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Metropolitan estuaries and sea-level rise: Adaptive environmental planning solutions at the regional scale

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Metropolitan estuaries and sea-level rise:

Adaptive environmental planning solutions at the regional scale

By

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ABSTRACT

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by

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Doctor of Philosophy in Landscape Architecture and Environmental Planning

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Wide estuaries are natural magnets for urban development. Several of the World's major cities developed around estuaries, but at the same time encroached upon some of the most complex and vital ecosystems. Sea-level rise threatens to submerge both rare wetland habitat and essential urban areas and infrastructure. This prospect discloses the urgency of balancing urban development and environmental protection in Metropolitan Estuaries. The hard task of dealing with this threat may provide the opportunity to promote an integrated approach to regional planning, where the necessary adaptation of cities to sea-level rise could equally promote the preservation, or even the enhancement, of wetland habitat.

The two case study metropolitan estuaries, San Francisco Bay (California, USA) and the Tagus Estuary (Lisbon, Portugal), share striking similarities in terms of morphology. They both host large metropolitan areas and important wetland ecosystems. Nevertheless, a finer analysis of development patterns reveals crucial differences in the extent of shoreline alteration and types of land use that now encroach upon natural estuarine habitat. The comparative study of both estuaries provides mutually beneficial insights on the shortcomings of each system, and helps identify opportunities to enhance coastal zone management, adaptive governance and environmental planning efforts.

The evolution of both estuaries throughout the Holocene is reconstructed, with special emphasis on the process of anthropogenic alteration. While this impact has been significant and continuous in the Tagus Estuary for over two millennia, large scale disturbance of the San Francisco Bay was concentrated in the last two centuries. The legal frameworks that have guided, with varying degrees of effectiveness, the process of wetland reclamation and landfilling share a common ancestry in the Roman Law. These have evolved continuously in Lisbon and the State has upheld with relative success the provision to keep estuarine lowlands in public control, even as they were steadily transformed to farmland. In San Francisco, a period of deep

disturbances over the Sacramento River's hydrology was coupled with extremely fast and under regulated development of lowlands. During a short period, the property of these lands, which would theoretically fall within the Public Trust, was transferred to local governments and private landowners, which led to their steady transformation onto salt ponds, industrial zones and even residential neighborhoods. As a consequence, the Bay Area now has extensive developed areas at very low elevations, vulnerable to low levels of sea-level rise, and remaining wetlands are now heavily encroached upon by urban development. Around the Tagus Estuary, while most original wetlands have long been drained for farmland, the remaining patches are adjacent to non-urban land uses, which could facilitate future efforts of restoration or allow wetland migration with rising seas.

A comparative modelling of sea-level rise flooding over existing land uses reveals that, while around the Tagus Estuary most reclaimed lowlands are reserved for farmland and urban development over landfill is limited, the extent of developed urban areas at very low elevations is much greater around the SF Bay, which renders the region more vulnerable to early stages of SLR. Nonetheless, both cities have begun to incorporate climate adaptation onto their main environmental planning blueprints, for which they can be seen as early adopters of local sea-level rise adaptation strategies. Through interviews with stakeholders and document analysis, the planning and decision-making exercises that led to the recent elaboration of the first Tagus Estuary Management Plan, and the Bay Plan Climate Change Amendment, are analyzed and discussed.

Lisbon benefits from a very simple, top-down, planning structure, with a handful of public entities directly communicating and articulating stakes and approaches along the planning process. A lack of transparency as to some specific interventions and a still somewhat incipient tradition of public participation have contributed to protract the Plan's final approval.

The Bay Area institutional framework is well-used to collaborative planning efforts, which are usually successful in articulating conflicting interests, but are prone to limitations derived from narrow, and often difficult to expand, mandates for environmental planning agencies, within an extremely complex, multi-level, governance structure involving three levels of government and very active interest groups.

While broad mitigation/adaptation strategies are decided at the National or State levels, the actual implementation of SLR adaptation measures often require a great deal of involvement of local actors. Given that it is at this juncture that adaptation takes a concrete spatial expression, this is also the moment when land-use conflicts arise. Local governments are left with much of the burden of mediating competing interests, between urban development, environmental protection, and other social demands. In some instances, the prospect of shoreline development may be very attractive for both property owners/developers and local governments, given the potential land value and economic benefits, but these have to be weighed against the medium-/long-term costs of defending these assets from rising sea-levels.

In San Francisco Bay, there is an increasing awareness of the challenges posed by SLR, but the institutional arrangements are complex, and communication between the different public agencies/departments is not always as streamlined as it could be. Some agencies and departments need to adapt their procedures in order to remove institutional barriers to adaptation, but path dependence is an obstacle. The several projects where different federal and state agencies are partnered with local governments highlight the benefits of a more frank and regular communication between public actors. It also emphasizes the benefits of a coordination of efforts and strategies, something that was eroded in the transition from government-led policies to a new paradigm of local-based adaptive governance.

Whereas the articulation of public actors is often easy to address by increasing communication and coordination, conflicts involving private landowners and developers may be much complicated by the threat of litigation. The lack of a strong legal backing to public environmental protection mandates is a major obstacle to shoreline planning around the Bay and elsewhere, and this is highlighted by the extreme caution of some public agencies in upholding their jurisdictions over private property. Environmental NGOs have, in the case of California, a big role to play, as they are able to resort to the same legal and lobbying instruments as the developers, and may help even-out the field between public stakeholders with limited legal and economic resources, and powerful private developers with nothing to lose. There is seemingly a sense of urgency in pushing for the development of shoreline properties, as public opposition to development on locations exposed to SLR is most likely to increase in the coming decades. At the same time, NGOs and public agencies are aware of the stress wetlands will be under as the rates of SLR increase towards the end of the century.

“Green”, or ecosystem-based, adaptation is already on the way around the Bay. Large scale wetland restoration projects have already been concluded, and further action now often requires articulation with the reinforcement of flood defense structures, given the level of urban encroachment. While levee setback, or removal, would provide greater environmental benefit, the need to protect urban areas and infrastructure has led to the trial of ingenious solutions for promoting wetland resilience while upgrading the level of protection granted by levees.

To my mother.

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LIST OF ACRONYMS

APA	Agência Portuguesa do Ambiente (Portuguese Environment Agency)
ARH	Administração de Região Hidrográfica (Hydrographic Region Administration)
BCDC	San Francisco Bay Conservation and Development Commission
CDFW	California Department of Fish and Wildlife
CDWR	California Department of Water Resources
CWRCB	California Water Resources Control Board
CWA	Federal Clean Water Act of 1972
EEA	European Environment Agency
EPA	United States Environmental Protection Agency

EVOA	Espaço de Visitação e Observação de Aves (Bird Watching Center)
FEMA	Federal Emergency Management Agency
HAT	Highest Astronomical Tide level
ICS	Inner Charleston Slough (Mountain View, CA)
IPCC	Intergovernmental Panel on Climate Change
MHW	Mean High Water level
MLW	Mean Low Water level
MSL	Mean Sea Level
NOAA	National Oceanic and Atmospheric Administration
NRC	United States National Research Council
RCP	Representative Concentration Pathway
RHA	Federal Rivers and Harbors Act of 1899
SBSPRP	South Bay Salt Ponds Restoration Project
SF Bay	San Francisco Bay (including San Pablo and Suisun Bays)
SFEI	San Francisco Estuary Institute
SFRWQCB	San Francisco Regional Water Quality Control Board
SLR	Sea-Level Rise
SPUR	San Francisco Planning+Research Association
UNEP	United Nations Environment Programme
UNSAP	United Nations Scientific Advisory Panel
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
WFD	European Water Framework Directive (Directive 2000/60/EC)
Y.B.P.	Years Before Present

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1 URBANIZED ESTUARIES AND SEA-LEVEL RISE

1.1 Estuaries

An estuary is “a partially enclosed body of water formed where freshwater from rivers and streams flows into the oceans, mixing with the seawater” (McLusky 2004). Estuaries go by several names, and this leads to some ambiguity over what constitutes an estuary. Via the definition, the wide San Francisco Bay is certainly *in* an estuary, but it is only part of a much larger system that also includes the San Pablo and Suisun Bays and may include part of the Sacramento-San Joaquin Delta. But an estuary can also be ‘simply’ the terminal stretch of a river, long and usually only gradually widening, as is the case with the Thames downstream from London or the Elbe, downstream from Hamburg. An estuary can go by several names: river (Thames), bay (San Francisco), harbor (Sydney), sound (Seattle), ria (Faro); while in the first situation the estuarine transition from river to open sea is not entirely perceptible in that the river’s morphology does not change dramatically (except for the tidal regime and salinity), in others, the estuary might easily be considered as a mere inlet of the sea (although there is mixing of fresh and saltwater and land-borne sediment yield). For clarity, I will be concentrating mostly on large, urbanized, estuaries with a clear sense of enclosure but that are also evidently wider than the river upstream. Examples of such estuaries are the San Francisco Bay, the Tagus Estuary (Lisbon, Portugal), or the Swan River estuary (Perth, Australia).

1.1.1 Estuarine ecology

Estuarine habitats are considered “some of the most productive areas on earth” (Kennish 1992: 119), ranking at the same level as coral reefs and mangrove swamps. And elevated productivity is maintained because of high nutrient levels in both sediment and water column” (McLusky 2004: 1). They form fundamental stepping stones along major flyways, especially for wading birds, for which they provide feeding, mating, breeding, and resting habitat. They also constitute important nurseries for several fish species, responsible for the health of the fisheries off-shore, and provide excellent habitat for countless species of birds, macro invertebrates, and mammals (Costa 1999, Conradson 1982, Brearley 2005, Atkinson 2001). Their shallow waters and silt mudflats provide the substrate for the fixation of seaweeds, sea grasses, and the salt-tolerant salt marsh plant succession.

The estuarine ecosystem, in temperate regions, is composed of a few major types of habitat: the mudflat (underwater except for low tide), the salt-marsh (just above the daily high-tide, submerged frequently in neap tides) and the coastal prairie (low-lying grasslands, with the saline water table very close to the surface). The man-made salt-ponds also provide, under certain conditions, good habitat. It is the close succession of these habitats that constitutes a perfect environment for a vast number of species of waterfowl. For instance, several wading birds depend on ephemeral lagoons formed on slightly higher ground for protection, but require the mudflats as feeding grounds. In estuaries, such environments can be found within close range.

Three interrelated major factors appear to control the estuary's natural functions: salinity, tidal range, and sediment yield.

Salinity

Estuaries range, by definition, between the salinity of freshwater, always less than 0.5, and that of seawater, about 35 to 37[1] (McLusky 2004: 2). Water with salinity within these limits is called 'brackish'. The area where the mixing of saline water and freshwater occurs is usually quite spread, in temperate zones. In these regions, where freshwater inflow is greater than evaporation, salt tidal water inflows near the bottom and progressively mixes with fresh water that circulates nearer the surface.

Circulation patterns can be very uniform, in linear, relatively narrow estuaries (Thames, Severn) or can be characterized by more complex patterns of vertical mixing and horizontal recirculation of water, as affected by the Coriolis force, in wide estuaries (San Francisco Bay, Tagus Estuary)[2]. These circulation patterns also affect significantly the distribution and deposition of sediment, especially finer sediment carried in suspension.

Sediment

Estuaries are depositional zones at the lower end of watersheds. As sediment transport is a direct function of velocity, where rivers flow at fast to moderate speeds, they are able to transport coarser sediment but, when they reach the lower plains where they form estuaries, they lose speed. While the top end of an estuary may still receive larger pebble or sand material, only the finer silts and clays are kept in suspension and recirculated around the estuary. A usually even greater input of very fine sediment is received from the sea via the tidal currents (McLusky 2004: 9). These combined suspended loads are then slowly deposited by the effect of slackened currents where the river and tidal currents meet, usually in the calmer middle and upper reaches of the estuary. Here, they form the substrate of the highly productive intertidal zone.

Tidal range

The circulation patterns mentioned before are deeply dependent on the tidal range of the estuary (after McLusky 2004): in macrotidal (4-6m amplitude) or hypertidal (>6m) estuaries, tidal currents can be extremely powerful and impede the fixation of stable flats; likewise, the depth of water in high tide is unsuited for saltmarsh

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[1] Salinity is expressed in Practical Salinity Units, a dimensionless unit (McLusky 2004:3)

[2] McLusky builds on Fairbridge and Davidson et al (1991) to identify 9 types of estuary. Among these are the Fjord (narrow, deep interior, shallow mouth); Rias (drowned river valleys, strong marine influence: Rias of northwest Iberia); Coastal plain (drowned, shallow and wide, river valleys: Chesapeake Bay); Complex (similar to Coastal plain, but affected by complex topography, driven by glaciers or tectonic activity: San Francisco Bay, Tagus Estuary).

vegetation (such as *spartina*) to develop; as such, macrotidal estuaries are characterized by very large, barren, mudflats. Although devoid of vegetation, they are still abundant with macroinvertebrates and provide excellent habitat form wading birds. Mesotidal (2-4m) estuaries are composed by the more characteristic succession of three biotypes: mudflat (drowned in high-tide); wide saltmarsh, dominated by *spartina* associations, which provide excellent habitat for water fowl and mammals; and low-lying coastal plains. Microtidal (<2m) estuaries typically host narrow but very stable intertidal zones.

Habitat connectivity
A few recent studies have addressed the issue of habitat connectivity in estuaries as a major determinant on the global health of the fish populations (Herzka 2005, Meynecke 2007): in ecologically impaired estuaries, the reduced level of connectivity and proximity of nurseries affect the yield of the fisheries; unlike in terrestrial habitats (that can be fully isolated by development), a patchwork of fragmented stretches of wetland habitat may still perform collectively as a viable and productive ecosystem, even if a few of the elements are lost to pollution or landfilling, as all the different elements remain connected by the estuary (Meynecke 2007). Only the systematic destruction of habitat or extreme impairment of the water quality can render estuaries lifeless (McLusky 2004), which arguably instills them with a greater level of resilience than terrestrial habitats. Wading birds, for instance, often use different spaces within a same estuary for resting, feeding and breeding, relying on this highly interconnected network of different habitats.

1.2 Urbanization of estuaries

1.2.1 Brief history of the urbanization of estuaries

The importance of fluvial and maritime transport to the vitality of cities was primordial throughout most of history. Only recently did the railroad and highway systems supersede water-borne transport for long-distance trade, and then not for very long hauls. As such, mercantile cities were virtually always characterized by having a good port. The port was the gateway to long-distance trade, and long-distance trade was, at different periods in history, the bloodline of the larger urban centers. This port should constitute a good harbor for sea-faring vessels (if long-distance trade was the *raison d'être* of the city) and as such good bottoms were essential to ensure navigability. This meant that these large port cities usually had to be located within the lower reaches of rivers, under tidal influence, or in natural harbors.

Although this was already the case with several Phoenician and Greek trade ports (Figure 1), the emergence of major port cities is best observable as medieval trade centers transitioned to the mercantile era. Lisbon, Seville, London, Amsterdam, Antwerp, and later Liverpool, Boston, New York, San Francisco, Shanghai, Sydney… The list of major port cities located at the tidal, sheltered harbors of estuaries is vast.

And a few of the factors determining the location and expansion of cities in estuaries remained remarkably consistent throughout history.[3]

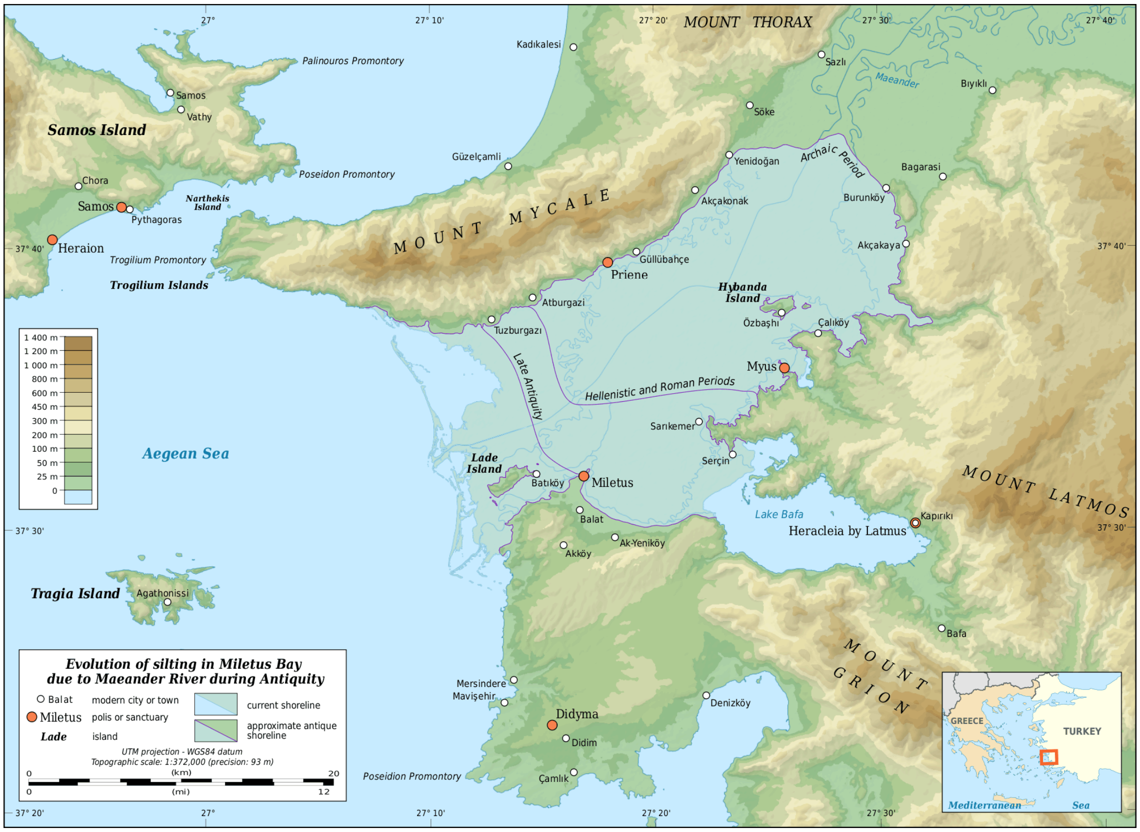

Figure 1 – Miletus (center of image), a major port city during the Hellenistic Period, relied on its strategic site on the natural harbor created by the Meander River's estuary. As the harbor became silted-in, likely due to major changes to the land-cover of the Meander's watershed, the port became unusable, and the city lost its purpose. (Image by Eric Gaba, Wikimedia Commons:Miletus_Bay_silting_evolution_map).

For the idealized capital of *Utopia*, Thomas Moore settled for a location at the furthest inland point along a major river that would allow a port for sea-faring vessels - London springs to mind as the inspiration (Figure 2).

[3] Hart (2001: 91): "San Francisco Bay is a harbor, a place to shelter and to anchor, to moor, to load and unload ships. It was the harbor that brought the Spanish and then the Americans here. It was the harbor that made this a metropolitan region. Even today, the harbor is a major support for the regional economy. (…) Yerba Buena Cove (…) had special advantages. Here mariners found a combination rare in these parts, deep water close to a gentle shore." (Morris 1979: 207) The Phoenicians had selected a similar location, next to an embayment on the north shore of the Tagus Estuary, where they founded Lisbon, 30 centuries before.

This location, at the upstream limit of the estuary where tidal influence still permits sea-faring ships to navigate, is akin to that of London, Hamburg, or Seville, Spain, which is located about 70 Km inland along the Gualdalquivir estuary (UNEP 2004).

The dominance of these port cities over entire regions arose from their control over long-distance trade, but other factors determined earlier settlement around estuaries. For a start, estuaries are usually surrounded by, or at the extremity of, large alluvial plains, with very fertile soils. As such, agriculture is typically highly productive in these regions, and estuarine cities were natural trade centers for this regional agricultural surplus. In some cases, the rich biodiversity of the region also provided a wealthy source of food and income, and hunting was a far-from-insignificant activity in the early stages of the settlement of New York and San Francisco (McCully 2007, Hart 2001). Also, being located at the confluence of river and sea, these port cities acted as command centers and transfer points: for the river-based transport, through which they dominated the natural *hinterland* formed by the watershed; for the long-distance, sea-based, trade, through which these large ports exported the goods produced by the *hinterland* and transformed in the city; and, especially, as gateways between the "global" and the "local" trade systems.

Figure 2 – Ortelius interprets Thomas Moore's description of Utopia and places the capital city at the most central location along the major river that would allow the creation of a seaport. (Wikimedia Commons:File:Utopia.ortelius).

1.2.2 Recent evolution

As technologies evolved, trade increased, and ships grew in size, port areas changed. First from a rather informal beach landing with a row of warehouses towards organized port infrastructure, with wide piers or docks extending further and further into the shores, reaching out for deeper waters (Meyer 1999). Port authorities became dominant institutions with land-use rights over vast stretches of estuarine shores (Brown 2008). These land-uses typically took full advantage of extensive landfilling and dredging, the impacts of which will be analyzed further ahead.

The already pronounced detach between urban areas and the estuary was often aggravated by the introduction of linear transport infrastructure, first the railroad, then the highways. In the end, the cities (now mostly metropolises) that had benefited from the port to achieve greatness, had lost their umbilical connection to the harbor. Tucked behind the girdle of two or three layers of infrastructure, cities now grew according to the expansion of inland transport infrastructure (first along railroad lines, then sprawling with the web of highways). The metropolitan center shifted steadily away from the port and original business center, as did residents.

Metropolitan estuaries (estuaries and the metropolitan areas than surround them) generally experienced the same trends in metropolitan evolution as other metropolitan regions. The driving forces of suburbanization (to use a neutral term) have been at work, with cities vastly expanding, shifting in scale, and changing their economy (Beuregard 2006). Having exploded in the United States, after the creation of the highway system, during the 50s and 60s, the process is ongoing. In Europe, after a slow start, the post-war era witnessed a steady onset of a new suburban model, although typically at a different scale and with different housing types (Southworth 1996). Sprawl has paved over entire regions, in Atlanta, Los Angeles or San Francisco, but also around several European cities (Bosselmann 2008).

1.3 Anthropogenic influence and the emergence of environmental protection

1.3.1 Impacts of human activity

Estuaries are especially vulnerable to pollution, as the patterns of circulation and enclosure tend to entrap and re-circulate pollutants over a longer period of time, where they would be dissipated over time in open coastal environments and along rivers. Kennish (1992) and McLusky (2004) list the different sources of pollution and their specific impacts over estuarine ecology.[4] These range from chemical pollutants, degradable or organic enrichment.

[4] Oil pollution is perhaps the most visible and infamous of these. Kennish (1992) cites the examples of Buzzard's Bay, MA oil spill, in 1969 (8 years of significant disturbance to the environment), and Chedabucto Bay, Nova Scotia, in 1970 (significant concentrations could still be detected 10 years after the spill). Frighteningly, these spills account for only about 25% of the total oil that reaches sea, as most

Several estuarine environments were subjected to widespread contamination from chemical pollutants and heavy metals, from industries, nitrogen and phosphorus, from agricultural runoff, or organic matter, from urban effluents. Needless to say that the combination of the three activities in the most explosive concentrations occurred in urbanized estuaries: here, the typical combination of a heavily cultivated agricultural *hinterland* and the encroachment by densely populated and industrialized port cities led to a generalized disruption of the natural environment, through direct destruction of habitat (filling, dredging), chemical and organic pollution, and introduction of exotic species. Also, being located at the downstream end of watersheds, pollutants floated down streams or carried in suspension tend to be trapped in the estuaries' recirculation and large quantities of heavy metals and other hazardous pollutants are affixed to the fine particles that deposit on the intertidal flats.

Turbidity, which is naturally dependent on the quantity of suspended fine particles on the water column, can prevent sunlight from penetrating deep into the water column. In estuaries that have experienced organic enrichment by urban and agricultural runoff, the reduced sunlight is a crucial limiting factor for phytoplankton growth, and potentially toxic algal blooms can be averted in highly impacted estuaries. In sediment-starved estuaries[5], turbidity is reduced and, as frequent blooms occur, anoxia ensues, triggering mass die-offs along food chain. The 'dead zones' thus created are some of the most gruesome and visible results of anthropogenic modification of estuarine ecology.

Fortunately, estuaries show signs of great resilience to pollution[6]: being naturally unstable systems (with highly variable current systems, temperatures, salinity, seasonal variation…), several of the species have adapted to withstand some degree of disturbance and still thrive. Nevertheless, the stress level to which some estuarine ecosystems have been subjected once appeared beyond recovery and without major changes to the management of watersheds and pollution control, a quick rebound is

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contamination is derived from industries, river and urban runoff (45%), and about 8% from normal operational losses of the shipping industry.

[5] Estuaries typically receive large sediment inputs from their watersheds. If the watercourses are blocked by dams or weirs, or if the amount of water diverted for human use is such that the capacity of the river to transport sediment is reduced or annulled, the input of sediment can be severely reduced. (Kondolf 1997, 2001, Barnard 2013, Schoellhamer 2013)

[6] The Thames estuary degraded to the point of full anoxia, in the 1950s, caused by heavy inputs of domestic sewage; treatment of effluents, starting in 1964, permitted a remarkable ecosystem recovery and, as the oxygen content in the water slowly increased, the fish diversity in the estuary bounced back from zero (!) fish species caught in the Thames, for the period 1920-60, up to a remarkable 120, by 2002. (McLusky 2004: 104)

unlikely. Particularly in the case of morphological modifications to the estuary, through landfilling or dredging, recovery without human intervention is often impossible. This type of direct and often irreversible impact is especially pervasive around heavily urbanized 'metropolitan' estuaries, where port activities, heavy industry, or garbage dumps, have long been encroaching upon the estuarine shoreline.[7]

In these estuaries that host large ports, the number of introduced exotic species is typically very high. They are, literally, shipped-in and released along with ballast water, and often cause severe disturbances to the ecosystem (Brearley 2005: 122, McLusky 2004). An extreme example, "the San Francisco Bay is the most altered aquatic ecosystem in the United States. More than 250 nonnative species of plants and animals have taken hold", and pressure from environmental groups has just recently led to the EPA being judicially mandated to regulate the discharge of ship ballast along the coasts. (Walker 2009: 119).

1.3.2 Metropolitan estuaries and the rise of the environmental movement

These recent environmental protection efforts are the natural evolution of a process that started over 50 years ago. As rivers before them, estuaries were for long perceived as inexhaustible dumping grounds (McLusky 2004: 95) and sources of unlimited bounty; not unlike the shocking extinction of the passenger pigeon[8], the possibility of large estuarine ecosystems facing a similar fate served as a potent wake-

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[7] Lisbon started early, landfilling a small inlet on the north shore of the Tagus Estuary in the early middle ages, to build a new quarter, the 'Baixa'. San Francisco Bay, likewise, was «(…)intensively used and sorely abused after the 1849 Gold Rush. The State of California wasted no time in turning over to private owners the entire shoreline and intertidal zone, which thereafter became the exclusive province of docks, factories, railroads, and warehouses.» (Walker 2009: 110). Over 80% of the historical extent of wetlands around the San Francisco Bay have been lost to development (Goals Project 1999), and roughly the same percentage was lost around the New York/New Jersey Estuary (Montalto 2004). Perth has all-but-eliminated the wetlands around the Swan Estuary (Brearley 2005), converting them mostly to residential, recreational, and industrial uses.

[8] "The passenger pigeon was so pervasive in the early 19th century so as to be considered an inexhaustible supply of cheap food. They are considered to have been the most abundant bird in the world and formed the largest flocks of birds ever recorded, only to be exterminated within less than a century. Audubon witnessed the flyover of one such flock in Ohio in 1813, and pondered that, even with all the hunting, "nothing but the gradual diminution of our forests can accomplish their decrease". He was wrong. Shacking trees so as to cause the nests, and the delectable chicks therein, to fall to the ground, or organizing massive shootings of flocks, did the trick and the last passenger pigeon died in a Zoo 101 years later" (McCully 2007: 130-131).

up call for environmental protection: that the ecosystem of bodies of water so vast as the Chesapeake and San Francisco Bays could be degraded close to the point of no return, was so alarming that they spurred environmental activism: "as the [San Francisco] bay reached its nadir in post-World War II era, a political movement broke out to save it in the early 1960s. Saving the bay was one of the first mass, popular mobilizations on behalf of the natural environment, here or anywhere in the world." (Walker 2009: 110-111)

The publication of the infamous *Reber Plan*[9], culminating half a century of widespread land filling of the San Francisco Bay (Conomos 1979), triggered a chain of events that would change environmental protection and activism, not only in the Bay, but the whole country.[10] The publication of a map by the Corps depicting the possible extent of fill resulting from the *Reber Plan*, in the *Oakland Tribune*, led a group of three women of the East Bay elite to initiate a movement to stop further filling[11] of the Bay.

Save the Bay was started in 1961 and quickly gathered public and political support that led to the passing of a State-mandated moratorium on filling and the creation of the Bay Conservation and Development Commission, through 1965's McAteer-Petris Act. The BCDC has, to this day, regulated all projects proposing modification or filling of estuarine habitat and has successfully prevented significant loss of wetlands since its creation (Walker 2009).

The fight for San Francisco Bay, along with the perhaps even more staggering appearance of the infamous Chesapeake Bay's *dead zones* in the 1970s[12], helped pave

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[9] This plan (Price 2002) proposed the damming of the San Francisco and San Pablo bays, and led to a study by the US Army Corps of Engineers (USACE) that predicted that by 2020 70% of the Bay was suitable for land-filling. See also Section 2.3.1 and Figure 8.

[10] In an unprecedented decision, USACE reviewed the project under a presidential mandate. For three years, the Army Corps conducted simulations of the effect of the two dams over the hydrologic system of the Bay and Delta. Obvious by today's standards, maybe not so by 1960s ones, the Army Corps reached a decision in 1960 that no further testing was necessary; they concluded that the plan's consequences were unacceptable, and specifically mentioned the grounds for rejecting it: "It would adversely affect the unique ecosystem." (Price 2002).

[11] The publication of this map in the *Oakland Tribune*, led to the three initiators of Save the Bay reprinting the map under the title *Bay or River?*. It was mailed-out to 1,000 houses as an incredibly effective recruitment tool (Walker 2009).

[12] Nitrogen and phosphorus pollution of the Chesapeake Bay are at the origin of algal blooms that deprived large areas of the estuary of oxygen. This leads to mass die-offs up the trophic ladder, from sea-grass and micro-invertebrates to crabs and fish. That the largest estuary in the country, covering an

the way to the creation of some of US's boldest environmental protection legislation: the Federal Water Pollution Control Amendments (later Clean Water Act), of 1972 (Kennish 1992: 388), that included severe limitations to the filling and dredging of wetlands, and a mandate for a much more rigorous control of pollution of all waters. In a similar process, the widespread elimination of wetland habitat around the New York-New Jersey Estuary (McCully 2007), likely as much as 75-80% of the historic extent (Montalto 2004), led to the creation of the Meadowlands Commission, in 1968 (Marshall 2004).

Of course, the environmental tribulations of urbanized estuaries are not exclusive to the United States. The same processes of encroachment and pollution affected estuaries all over the world. In other developed societies, the process of environmental protection was equally influenced by the scale of the environmental impacts experienced by estuaries.

The Swan River estuary, in Perth, Western Australia, still experiences algal blooms and massive fish die-offs.[13] Although there is evidently a lot to be done, the fact remains that the Swan estuary has been the subject of some of the foremost environmental protection legislation, due to the visibility of the environmental impacts of agriculture and encroachment by the metropolitan area of Perth: the first committee set-up to deal with the purity of water and cleanliness of the estuary's foreshore was established as early as 1943, and the Swan River Conservation Act of 1958 established the Swan River Conservation Board. The occurrence of algal blooms is now being fought through changes to agricultural practices on the whole watershed (Brearley 2005).

In Lisbon, Portugal, this link between estuaries and environmental awareness and protection is also present. As early as in 1836, a company was set up to manage (through what are now considered to be sustainable practices) the vast expanses of agricultural land, the *lezíria*, around the Tagus Estuary[14] (see Section 2.3.1). The

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area only slightly smaller than the State of Connecticut, could be so severely impaired by the combined effluents from its watershed was a dramatic demonstration of our collective destructive capacity, much along Garrett Hardin's argument in *The Tragedy of the Commons*, published in 1968.

[13] The more enclosed nature of the estuary, the reduced surface of water (as compared to the San Francisco Bay, for instance) and extreme seasonality of the inflows from the Swan-Canning river system all contribute to occasional flushing of high concentrations of phosphorus and nitrogen onto the estuary; in an unseasonal storm in January, 2000, this process led to the whole estuary being closed to all human activity due to a massive bloom of poisonous alga (Brearley 2005: 102).

[14] The *lezíria* is a type of man-made low-lying agricultural land, regulated through a system of canals and low sustaining walls, that has proven to be a sustainable agricultural practice ever since.

intrinsic value of these lands was again recognized in 1964, when a Regional Plan prevented potential urban development on the best habitat and agricultural land around the estuary. Although this may not have been an express concern of the plan, but rather the directing of development towards more suitable land, the result is that the northeastern part of the estuary was kept in very good condition until the first natural parks were created, after the Revolution of 1974. Then, once more, the value of the estuary was asserted when the Tagus Estuary was included in the first group of Natural Reserves[15] created in 1976. Although historically the Tagus estuary has experienced severe impacts, from agricultural, industrial and urban discharges of pollutants, the high turbidity appears to have prevented major algal blooms from occurring (Ramiro Neves, cited in Garcia 2011).

A few major disasters, such as the 1966 accidental spill of 700 tons of sulfuric acid from the CUF plant, led to the elimination of a few iconic species, such as the Portuguese oyster, but recent legislation (National and European, see Sections 2.3.1 and 3.3.1) have led to the progressive treatment of all sewage, and the estuary has been showing signs of recovery. A multi-decade plan to collect and treat all sewerage around the Tagus Estuary has just been completed. Even before an emblematic urban sewage collector started diverting the last remaining untreated outlets within the city of Lisbon to a newly-expanded treatment plant, the improvements to water quality, not the least from the much-reduced activity of the heavy industries surrounding the estuary, were already visible and reflected in the growing abundance of fish species (Garcia 2011, Cabral 2001).

1.3.3 Current Issues in the management of urbanized estuaries

The recent concentration of port activities in large container terminals is releasing waterfront for redevelopment or restoration. Whether to create business centers or housing condominiums; provide public facilities, public open space or other amenities for the populations; or to restore wetland habitat along these coveted shorelines, becomes the fighting ground between several vested interests, both private (promoters, land owners…) and public (port authorities, environmental protection agencies, city governments…) (Meyer 1999, Brown 2008, ULI 2004). The citizens have gained growing influence: increasingly, the traditional lobbies are now joined, or fought against, by several environmental or social activist associations, whose interests range from saving wetland habitat, to the creation of more public open areas, or the protection of built heritage.

Unique conflicts emerge from clashing interests, even when they could all be considered in the “public interest”: in Lisbon, the proposed expansion of the Alcântara

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[15] The Natural Reserve is highest level of importance after the only National Park in the country, the Peneda-Gerês. The Tagus Estuary Natural Reserve was created by the *Decreto-Lei nº575/76 (July 19th)*, recognizing its “fundamental and irreplaceable economic and ecological roles” and protecting its “extreme [biological] richness”, under the Ramsar Convention of 1971.

container terminal (publicaly owned, privately operated) generated much opposition from the residents of a nearby hillside neighborhood, that thought the added containers would interfere with their views of the river; in New York, NIMBY practices have turned the implementation of necessary infrastructure into a topic of hot debate in the new field of environmental justice (Sze 2007); SF Bay is host to several such disputes. The largest proposed development on former Baylands, the Redwood City Saltworks, will be further discussed in Chapter 4, as will these emerging land-use conflicts.

Compromise has not always been the rule of the game and some entities, especially port authorities, have been less than willing to negotiate in the past. Lisbon Port Authority was, until recently, still considering a proposal to create a giant jetty over the Tagus river's spit that would allegedly decrease the silting of navigation channels, with little concern over the consequences to the natural environment. Nevertheless, the greater public involvement has changed, if ever-so-slightly, the decision-making process and the balance of power: with enough uproar, most proposals that seriously impact the shoreline now seem growingly subject to compromise and improvement.

The management of estuaries, formerly done according to strictly top-down, *sectoral*, and often conflicting perspectives, failed for long to tackle the threats to the estuarine ecosystem. As of recent, a more collaborative and transparent approach to local governance, integrating land-use planning and natural resource management, is being pushed forth in several developed nations. Integrated estuary management plans now serve as platforms for the promotion of sustainable ecosystem management, pollution control, and adequate planning of shoreline uses and environmental stressors (McLusky 2004: 158, BCDC 2008).

So, after a period of profound abuse and neglect, improvements to the environmental health of estuaries are starting to show, especially in developed countries.[16] As pollution control and sewage treatment are implemented, the water quality will, given

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[16] "The management of nutrients and carbon inputs has virtually eliminated dead zones from several systems, including the Hudson and East Rivers in the United States and the Mersey and Thames Estuaries in England." (Diaz 2008); in the Chesapeake Bay, the management of sewage and pulp mill effluents has led to many small-scale reversals in hypoxia, even if overall the system is still experiencing extreme rates in loss of biomass (mostly sea grass, micro and macro invertebrates). Jacksonville, NC, has concluded an extremely successful program to clean-up and recover Wilson Bay through what looked as a desperate attempt at re-introducing oysters to the heavily polluted system: "The oysters did not simply live. They thrived. (…) As the oysters filtered the detritus and consumed it, the water became cleaner and as it became cleaner, the benthic community reestablished itself. That attracted fish, which in turn attracted birds. Soon even sea otters splashed in the bay." (Moore 2009: 88).

time, improve dramatically. If the destruction of wetland habitat is equally halted, estuaries seem to possess an excellent capacity of self-healing.[17]

Wetland restoration

Larger wetland restoration efforts have spread around several estuaries. In the San Francisco Bay (Williams 2001), and the South Bay Restoration Project is the largest tidal wetland restoration project on the West Coast of the United States. Specific interventions range from relatively simple actions on degraded habitat so as to restore lost functions, to more complex projects to create these wetlands from scratch.

These interventions could be qualified as the creation of artificial wetlands. The Goals Project (1999) assessed common causes of (technical) failure, frequent in some of these restoration efforts:

- Inability to re-create all of the functions of a natural marsh;

- unrealistic design, siting or size;

- the requirement to undertake mitigation on the same site as the development impact often resulted in mitigation projects being sited in disturbed or marginally suitable locations;

- a lack of clear or realistic objectives frequently made it difficult to determine whether a wetland project was a success or failure (to which Kondolf (2000) and others would append the need for post project appraisal and monitoring).

The San Francisco Bay has, to a large extent, functioned as a testing ground for wetland restoration, but experience has allowed some of the earlier mistakes to be corrected. The efforts of habitat restoration are now a welcome and integral part of the process of ecosystem recovery that the San Francisco Bay has been going through (see Chapter 4).

There has been an ongoing debate over the relative merits of environmental restoration. Nassauer (1995) reminds that ecological function and naturalness are not

[17] «The environmental movement to save the bay reversed a century of degradation. Since the Bay Conservation and Development Commission has been established in 1965, the bay has shrunk no further and has had hundreds of acres of wetlands restored. Its waters are no longer rank, and aquatic life is abundant, with shorebirds in large number feeding along the mudflats and marshes. Most important, the nay is now seen as a vast scenic, recreational, and ecological open space, instead of a dour transportation hub and industrial landscape. Some 180 of 275 miles of bay shoreline are now open to the public, compared to only 5 miles when the blue-green revolution began. The bay has come back as the visual centerpiece of the metropolis, a watery commons for the region, and a source of pride to Bay Area residents.» (Walker 2009: 111).

necessarily synonymous, as Nature is a social construct: restoring ecological function is (or should be) the purpose of environmental restoration, but should not be confused with design criteria, at least not in the aesthetic sense of design. The 'neatness' expected from the 'well-kept' landscape is often not present in strictly functional projects; although these are likely to perform well in the ecological dimensions, they might be misinterpreted as 'failures' by a less-informed observer, because they lack visual 'cues' that attest their validity and performance.[18]

Mozingo (1997), reinforces this point, and proposes ways through which ecological designs can incorporate principles of landscape design so as to make them 'readable' to an observer.[19] By introducing a few common elements of landscape design, restoration efforts may be made not only ecologically, but also socially valid. Especially in artificial wetlands, that create habitat rather than restore it, there should be a preoccupation as to the didactic value of the intervention, by incorporating features that make the ecological function an enjoyable sight (something as simple as interpretation signs and clear 'gateways' may do a lot to improve this…).

Wetland restoration in metropolitan estuaries has some specific merits, in that it deals with a rather 'wild' natural feature within a highly artificial environment. Estuaries, when not completely degraded, are the largest ecologically functional ecosystems within their metropolitan regions, somewhat subverting the historical push towards the dichotomy between Man and Nature as incompatible realms. Cronon (1995) brilliantly argues that the romantic quest for the unspoiled and idyllic *wilderness* might prevent the urban dweller from perceiving, and thus valuing, the *wildness* at the door-step.[20]

Restoration efforts may easily fall into the trap of the 'technological solution' that renders bad habits 'sustainable': in his much-misunderstood critique of restoration, Katz (1992) ends up highlighting this crucial point: «we are not restoring nature; (…)

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[18] Nassauer (1995: 248): «The general design principle we can use to guide design and policy is to label ecological function with socially recognized signs of human intentions for the landscape, setting expected characteristics of landscape beauty side by side with characteristics of ecological health».

[19] Mozingo (1997): «Ecological designers may presume that the ecological value of a landscape will speak for itself. (…) What is visible is the surface manifestation of ecosystems and the material conclusions of ecological process. (…) The ready perception of the surface features of ecological systems (…) suggests the particular importance of access and pathway to create viewpoint and contrast in ecological design. (…) where and how the ecological and the cultural interact should be obvious and celebrated.»

[20] Mozingo (1997) sums it up: "A land ethic born from a wilderness vision inevitably leaves the city as wilderness's discomfiting and degraded opposite."

Nature restoration is a compromise; it should not be a basic policy goal. (…) it cleans up our mess. We are putting a piece of furniture over the stain in the carpet, for it provides a better appearance. As a matter of policy, however, it would be much more significant to prevent the causes of the stains. » If there is a perception that all errors might be remedied, the underlying principle of restoration as an *improvement* of the damaged natural function (Atkinson 2001) might be put in jeopardy by a less acute sense of cause and consequence.

This warning seems particularly adequate to the climate change debate: just as restoration efforts are starting to spread throughout the developed world, sea-level rise threatens to drown the new wetlands, along with the original ones and quite a few of the low-lying urban areas… Idly standing by, in face of this challenge, is simple not an option.

1.4 Sea level rise: how much, by when?

The scientific debate over SLR has long moved from whether it is happening, and it now focuses on the determination of rates of sea level rise, spatial variability in sea level elevation and what factors affect this. The challenge now is increasing the accuracy in determining local impacts/effects of rising sea levels.

The latest IPCC report establishes a range between 0.26 to 0.55m as likely if major progress is achieved in curbing emissions, and 0.52 to 0.98m in the projected worst-case scenario (IPCC 2013: 13-14, Table 1). The same report concludes that, based on current understanding, "only the collapse of marine-based sectors of the Antarctic Ice Sheet, if initiated, could cause global mean sea level to rise substantially above the likely range during the 21st century. This potential additional contribution cannot be precisely quantified but there is medium confidence that it would not exceed several tenths of a meter of sea level rise during the 21st century." (IPCC 2013, pp.13-14). While not entirely reassuring, the report, which is for the most part an aggregation of scientific research, sets a manageable timeframe for adaptation for most developed nations. The survivability of island nations, or the odds some types of wetland ecosystems will have in adjusting to the rates on the high end of the spectrum, are still major challenges, even if unclenching of polar sheet ice is averted.

As of late (past decade), the IPCC and UNSAP have been adopting a cautious approach to the form of communication of scientific data and results, a 'calibrated language' to express the confidence in and/or likelihood of specific findings. This is most effective when there are a very large number of contributions, so as to allow for a quantitative assessment of confidence and uncertainty. The shift in the style of results communication is especially evident in the transition from IPCC's AR4 (IPCC 2007) to AR5 (IPCC 2014).

Even under this very cautious approach, IPCC communicates that further sea level rise past 2100 is nevertheless inevitable, and paleo sea level records indicate that sea level exceeded 5m above present when global temperature was up to 2ºC warmer than pre-industrial:

«Cumulative emissions of CO_2 largely determine global mean surface warming by the late 21st century and beyond. Most aspects of climate change will persist for many centuries even if emissions of CO2 are stopped. This represents a substantial multi-century climate change commitment created by past, present and future emissions of CO2 (...) A large fraction of anthropogenic climate change resulting from CO2 emissions is irreversible on a multi-century to millennial time scale, except in the case of a large net removal of CO2 from the atmosphere over a sustained period.» (IPCC 2013, SPM-15).

		2046–2065		2081–2100	
	Scenario	Mean	*Likely* range[c]	Mean	*Likely* range[c]
Global Mean Surface Temperature Change (°C)[a]	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
	Scenario	Mean	*Likely* range[d]	Mean	*Likely* range[d]
Global Mean Sea Level Rise (m)[b]	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

Table 1 – Global mean temperature change and mean sea-level rise according to each emission concentration path scenario (IPCC 2013: SPM-2).

So, even under IPCC's cautious assessement, we have already committed to several centuries of SLR, which could represent up to 5m above current MSL. Uncertainty may hinder the capacity or willingness of policymakers to advance adaptation agendas and spur active adaptation measures, but what is known is defenitively not an impediment of resolute action, in the eyes of the European Environmental Agency:

«The lack of perfect information is a common feature in all areas of policymaking. Uncertainties must not prevent taking decisions but it is in the interest of policy-makers to be aware of the degree of uncertainty associated with specific data sources so that they can consider the range of plausible developments in their decisions. The importance of uncertainties about climate change and its impacts for a particular decision depends on factors such as the time horizon and reversibility of the decision, the importance of climate factors for the decision, and the costs of buffering the decision against uncertain developments. For example, when uncertainties are very large, it is often (but not always) prudent to focus on 'no regrets' and 'win-win' adaptation strategies that address adaptation to (uncertain) climate change jointly with other societal goals, thereby limiting the additional cost of the adaptation component.» (EEA 2012b: 43)

Sea-level rise (SLR) has been described as a "slow moving emergency" (Gordon 2014). It challenges common perceptions of what constitutes a natural disaster in more than one way. It is, for the most part, a consequence of anthropogenic actions, but not directly so: Climate Change can now reliably be attributed to human action (IPCC 2014), but the mechanisms through which this global change produces SLR are far from simple and are still not fully understood (IPCC 2013, IPCC 2014). What is known is that SLR has been happening at an accelerated rate for at least a century, and will accelerate in the near-future (NRC 2012). Also consensual is the idea that past emissions of greenhouse gases alone will produce effects over the global sea level for several centuries.

This concept is, in itself, a major challenge to common perceptions of impending "danger". Crisis and risk management are often closely associated with a sharp awareness of the risks of inaction, or protracted action. Every time a flood hits a floodplain, for instance, it helps reinforce a notion that people might already have, and most policy and planning officials are most likely aware of: there is exposure to a risk (EEA 2012b:45), that vulnerability is often recognized (EEA 2012b, Adjer 2006), and people have a few reliable ways to avoid it, if they are willing to so (EEA 2013). SLR itself, on the other hand, is a new challenge, and is yet to express itself fully in a way that renders it obvious to the general public. People are unable to process hypothetical scenarios in the multi-generational scale, which makes it hard to communicate danger and make the issue a relevant one for policy-makers.

The early "doomsday" communication techniques, where the scientific community conveyed the full extent of SLR's plausible impacts with abandon, were not entirely successful in transmitting the message to the general public (Feinberg 2011). It is, in this respect, a problem more closely resembling that of communicating the risk of a very large earthquake striking a given area: they are usually devastating events, but might have a recurrence interval of a few centuries. Finding the right balance between raising unnecessary alarm and letting the issue fade into oblivion is often challenging for the scientific community and decision-makers: too many "false alarms" might expose scientific knowledge to (often unfair) challenges, in a "boy-who-cried-wolf" type of situation; too little, or too infrequent, communication of the risk renders it virtually unknown to the general public.

Precision is essential: using the term "global warming" rather than "climate change", while equally correct, exposes scientific knowledge to uninformed attacks such as the typical "how come the planet is warming up if there's an epic blizzard out there?!" type of argument (Schuldt 2011, Whitmarsh 2008). Yet, a little cunning could go a long way. While SLR is, for the most part, "invisible", the extreme climate can be very easily associated to it, and the aftermath presents an opportunity to inform the general public while climate is under the media spotlights (IPCC 2012, Carey 2011).

In fact, it is now evident that two extreme storm events – Katrina, in 2005, and Sandy, in 2012 – were paramount in mainstreaming SLR adaptation into US media and political agenda (Tollefson 2012). It could be argued that the latter, in particular, while having had a (fortunately) reduced death toll, was particularly effective in conveying the message, as it struck US centers of power and decision-making. This is a cynical, yet pervasive, issue: the "it could happen to us" is still an exceedingly powerful concept, and "us" often means narrowly those with power.

While the political environment in 2005 and 2012 should necessarily be taken into account, it is obvious that the media attention granted to storm surges was fundamental in raising awareness to coastal hazards. In the words of John Laird, Secretary of California's Natural Resources Agency:

> *"the situation is not a bathtub where there is only gradual rise. (…) it is the 2-year old child jumping into the bathtub, which is the extreme event. And it is the extreme event that will especially drive the message home on what sea-level rise is and what its effects are on the coast." (Gordon 2014:4)*

To be absolutely rigorous, extreme events such as hurricanes or epic surges did occur before late Holocene climate change was unclenched; it is the frequency with which the most extreme events occur that is alarming (IPCC 2012, Birkman 2010). Be it as it may, climate change and its impacts are finally in the public agenda for most developed (and quite a few developing) nations, and coastal zone management is deserving of a special attention.

This may not only be related to the media attention surrounding the impacts of recent storm events (such as Sandy and the 2013-2014 Winter Storms in the Atlantic Coast of Europe), but also to an increasing awareness that most of the damages and casualties can be attributed to more or less crass planning and policy choices: risk[21] is a function of hazard and exposure; simply put, if a huge hurricane strikes an unpopulated or extremely well prepared/protected shoreline damage will be minimal, in the same way a major earthquake in Japan or in Haiti will have vastly disparate impacts. Planning mistakes of today may prove exceedingly expensive in the near-future.

In the very definition of the word *vulnerability*, which can be directly correlated to risk, the human component is evident: vulnerability is "the quality or state of having little resistance to some outside agent; the state of being left without shelter or protection against something harmful" (Merriam Webster). While the hazard itself is often uncontrolable, risk may be averted or mitigated (namely through risk avoidance strategies, including removing vulnerable structures or setting up efficient evacuation strategies), and vulnerabilities can be addressed through proactive adaptation (increasing the sturdiness of built structures, protecting valuable or strategic assets in the more exposed areas) (IPCC 2012). Given that the hazard itself, in the case of coastal storms, is a more or less uncontrollable variable, the mitigation of risk lies precisely in reducing the level of exposure to it – by addressing current vulnerability.

This recognition of past mistakes, while far from easy, is essential as a trigger for change. Change in policy, legal standards, and land-use/planning practices. Risk-avoidance strategies often entail, over flat and exposed coastlines, dramatic shifts in

[21] Very intersting takes on this issue come, unsurprisingly, from those agents dealing with insurance and security: http://www.pinkerton.com/blog/risk-vulnerability-threat-differences; http://www.threatanalysis.com/2010/05/03/threat-vulnerability-risk-commonly-mixed-up-terms/

long-standing practices and cultural attitudes. The perseverance and willingness to rebuild displayed by local populations along the Mid-Atlantic US coast after Sandy stroke, while certainly worthy of praise, may be ill-advised: the level of exposure to risk along those sandy (no pun intended) coastlines would demand a thorough and honest weighing of the benefits and the risks of rebuilding, in place where one is, scientifically speaking, certain another disaster will fall.

The issue with exposed coastlines is not *whether* a major event will occur, but rather *how often* and *how big* that event will be. And climate change's contribution to an exacerbated risk is two-pronged: there is a growing consensus that the frequency and intensity of storms may increase in the future; and the elevated eustatic sea levels expected in the future will increase the hazard they present to any given coastline.

1.5 Problem statement: Metropolitan estuaries and Sea-Level Rise

Metropolitan estuaries combine characteristics that make them especially vulnerable to sea-level rise: they host large expanses of low-lying alluvium, located just above current MSL; vast expanses of these lowlands are often occupied with urban areas and infrastructure along the shorelines; and urban development has encroached upon (and severely disturbed) wetlands, which are highly sensitive to fluctuations in sea level. As such, the threat of SLR is a very real and eminent prospect in these settings (Diez 2011).

The potential losses (economic, social, and ecological) to SLR could be astronomical (Ericson 2006, Heberger 2009, EEA 2012a and 2012b, ANPC 2010, Strauss 2012), as many of these metropolitan estuaries are characterized by having their most valuable assets located on, or near, the waterfront. The level of exposure of central business districts, historic centers, and crucial infrastructure, such as ports and airports, makes adaptation to SLR a matter of survival for these cities.

The costs of early adaptation to SLR have been assessed by different sources to be much smaller than the future costs of hasty reaction (EEA 2013, Gordon 2014, Pendleton 2008, RAE, n.d.). As such, several of these metropolitan areas have begun to address this threat through regional planning and some local adaptation actions.

As urban areas, vital infrastructure, and irreplaceable wetland habitat would, in their present condition, be severely affected by sea-level rise, inaction is no longer an acceptable attitude. The possibility of protecting urban areas and infrastructure simply through the construction or reinforcement of levees would in all likelihood prove to be but a temporary solution, as sea-level is expected to keep rising far beyond the estimates for the year 2100.

Also, some of the more radical technological solutions might in fact contribute to worsen the flooding problems elsewhere, as is often the case with heavy-engineered coastal protection: besides conveying a sense of false security that may encourage further development behind these structures, introducing levees or sea-walls might contribute for sediment starvation along non-protected shoreline and increase the energy of tidal currents and storm surges over unprotected areas. A more resilient attitude could consider planning in advance for the progressive relocation of crucial urban functions and infrastructure to higher ground, allowing the existing and expanded wetlands to work as natural buffers against the ever-more-frequent storm surges (Beatley 2009, Titus 2011, SPUR 2011).

Walker et al (2004) define resilience as "*the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks."* This definition draws on Holling's previous work and is expanded by Beatley (2009). Although the concept of resilience may be ambiguous, this precise definition perfectly fits the vision of a sustainable, viable, metropolitan estuary in face of ever-changing conditions: Sea-level rise may produce irreversible modifications to both urban and natural environments around estuaries, but there seem to be solutions that would allow for the vital functions of both to be retained. Heavily-engineered technical solutions, such as sea-walls and levees, may help protect vital urban infrastructure, but the consideration of passive approaches, such as the planned withdrawal to higher ground, and the protection and expansion of wetlands, could help preserve crucial habitat and also act as a damper preventing direct impacts from storm-surges (Goldie 2006, IPCC 2007, SPUR 2011, Titus 2011).

For that to happen, estuarine ecosystems demand special attention. As mentioned before, these ecosystems have experienced severe disruption from anthropogenic action. Just as they are showing signs of improving health in developed countries with higher environmental protection standards, they are now faced with a big challenge from SLR. Most salt marshes will likely be unable to keep up to future rates of SLR unless proactive action is taken so as to enhance their capacity of accretion[22] or to permit their slow migration upland (Middleton 2012, Woodroffe 1990, Morris 2002, Temmerman 2003, French 2006, D'Alpaos 2007, Kirwan 2007, 2010, Mudd 2009. See also Chapter 4). Within urbanized settings, armoured shorelines make this an especially tasking exercise.

Accretion (the vertical growth of wetlands, in response to higher water levels) is improbable if the rate of rise is too fast. Only the perfect combination of high inputs of sediments from the watershed and the presence of plant species already adapted to high variability (those in estuaries with meso- or high-tidal ranges) can reasonably be expected to keep up with rising sea levels. For the highest rates of SLR being considered towards the end of the century, only the migration of wetlands would preserve them.

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[22] «Wetlands are generally able to keep up with moderate rates of sea level rise by accreting (building up in place). There are two major processes of accretion: organic build-up and mineral sediment trapping. (...) the response rate of accretion to varying degrees of sea-level rise is poorly understood, leaving open the question of when a wetland surface may become unstable due to insufficient sediment supply and organic matter accumulation, [is] commonly referred to as the threshold of resilience.» (Middleton 2012: 86)

This would be possible only where gentle slopes inland from their current extent are unobstructed by man-made barriers, such as levees, highways or railroads (Goldie 2006, Bird 1993). Wetland preservation is thus possible under the more conservative estimates of sea-level rise (IPCC 2007: 329, Allen 1995, Bird 1993, Chmura 1992, Krone 1985, Morris 2002, Reed 1990, 1995, Simas 2001, Temmerman 2003, see also Section 4.3.4), but incompatible with urban encroachment without significant measures, wich could include the relocation of existing urban development (Goldie 2006: 251-258, BCDC 1987, 2008, IPCC 2007, SPUR 2011).

The following chapters take as case studies two metropolitan estuaries sharing striking morphological and climatic similarities – San Francisco Bay and the Tagus Estuary in Lisbon, Portugal – to analyze how they have evolved and which may be the underlying causes for their diverse development patterns (Chapter 2), how the environmental governance structure works and how it has been addressing more exigent environmental standards and incorporating SLR (Chapter 3) and, finally, what are the emerging conflicts and opportunities arising from local adaptation (Chapter 4).

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2 EVOLUTION OF TWO URBANIZED ESTUARIES: ENVIRONMENTAL CHANGE, LEGAL FRAMEWORK, AND IMPLICATIONS FOR SEA-LEVEL RISE VULNERABILITY

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2.1 Introduction

The estuaries of the Sacramento River, California (San Francisco Bay) and of the Tagus River in Portugal (Figure 3) share many commonalities in topography, hydrology, and climate. Both face threats from accelerated sea-level rise, but the exposure of urban areas to rising waters is significantly greater in San Francisco Bay than in the Lisbon Estuary (as will be discussed in Chapter 3). In this paper, we explore differences in the historical evolution of these two estuaries, and key divergences in the legal and institutional histories, such as the degree to which tidelands have historically been treated as public lands, how the 'high-water' limits of public trust are defined, and how the public trust zone migrates with coastal erosion. We argue that these differences can largely explain the contrasting situations in which the two estuaries find themselves as they confront sea level rise.

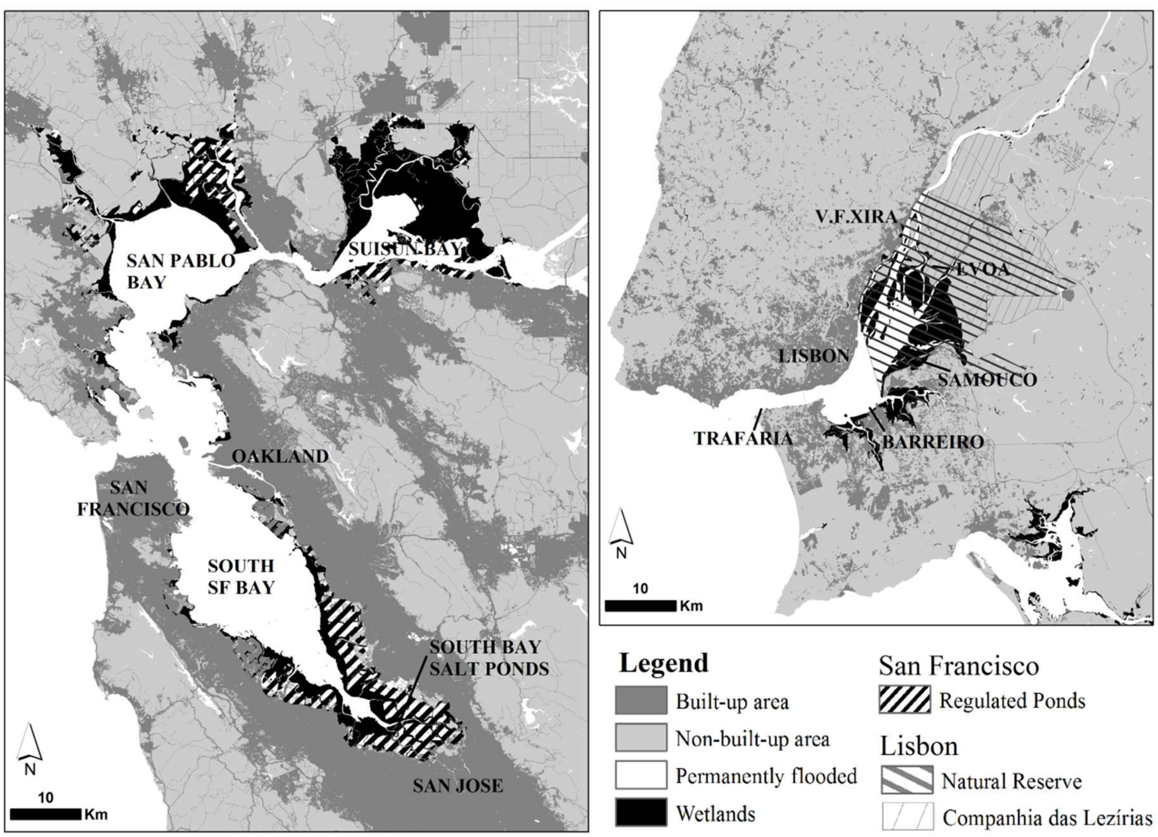

Figure 3 – Side-by-side context maps showing both estuaries at the same scale and locations mentioned in the text.

The San Francisco Bay, California (henceforth, SF Bay), is the largest estuary along the west coast of North America. The Tagus Estuary, Portugal (henceforth, the Tagus Estuary), is the largest estuary on the Atlantic coast of Europe (Table 2). With an area of ~1260 km², SF Bay is significantly larger than the Tagus Estuary, ~320 km² (EPA 2011, APA 2013). Both provide critical wetlands habitat along major flyways and are crucial as nurseries replenishing fish stocks offshore (Okamoto 2011, Catry 2011, Costa 1989, Costa 1999). Both SF Bay and the Tagus Estuary are surrounded by large metropolitan areas, with the San Francisco Bay Area being, with a population of about 7 million, the second largest metropolitan area on the Pacific coast of North America, and the Lisbon Metropolitan Area, with about 3 million inhabitants, being the largest urban center located directly on the Atlantic Coast of Europe. Geomorphologically, both estuaries are "drowned valleys", marked by alternating episodes of active incision during ice ages and marine transgression during warm periods (McLusky 2004). Thanks to rock type and active tectonics, both estuaries have "bottlenecks" at their mouths, with wide inner basins and inland deltas. The Mediterranean-type climates of both estuaries results in large seasonal and inter-annual variability in precipitation and fresh water inputs.

Metropolitan Areas	**San Francisco Bay Area**	**Lisbon Metropolitan Area**
Population	7,150,739[a]	2,821,876[b]
Total area [Km^2]	17,931	3,002
Pop. Density [people per Km^2]	399	940
Estuaries	**San Francisco Bay**	**Tagus Estuary**
Water surface at high tide [Km^2]	1,260 [c]	320 [d]
Mudflats [Km^2]	118 [e]	152 [f]
Low marsh [Km^2]	19.9 [g]	4.4 [h]
Salt Ponds [Km^2]	239 [i]	<1
Mean tidal range [m]	2.3 [j]	2.4 [d]
Mean tidal prism [m^3]	14.7×10^8 [k]	7.5×10^8 [d]
River basins	**Sacramento - San Joaquin Basin**	**Tagus Basin**
Surface area [Km^2]	153,794	80,629
Average annual unimpaired flow into estuary [hm^3]	34,819 [l]	17,044 [m]
Average annual flow into estuary [hm^3]	~25,000 [n]	~12,500 [l]
Average annual sediment influx into estuary [metric ton/year]	$1\text{-}2 \times 10^6$ [n]	$1\text{-}5 \times 10^6$ [o]

[a] Bay Area Census (MTC-ABAG, 9 Bay Area Counties, 2010 Census); [b] Instituto Nacional de Estatística (2011 Census, NUTS II - Lisbon); [c] EPA 2011; [d] Gameiro 2007; [e] SFEI Baylands *"Bay Flat Total"*; [f] DGT COS 2007 *"Mudflats"*; [g] SFEI Baylands *"Low and Mid Marsh"*; [h] DGT COS 2007 *"Coastal wetlands"*; [i] SFEI Baylands *"Salt Ponds"+"Regulated Ponds"*; [j] Palaima 2012; [k] Gilbert 1917; [l] CDWR 2007: 48; [m] Santos 2002: 144 ; [n] Barnard 2013; [o] Costa 1999

Table 2 – Statistics for the SF Bay and Tagus Estuary.

2.2 Materials and methods

2.2.1 Reconstruction and mapping of Environmental Histories

We reconstructed the environmental histories of both estuaries, drawing upon primary such as historical maps and documents, and modern paleogeographic reconstructions (Table 3). Map sources were scanned, georeferenced, and processed on GIS software to delineate shorelines and identify (when possible) wetlands, urban areas and infrastructure. It is important to note that older map references (e.g. Seco 1561, Cañizares 1776) did not adhere to current standards in terms of their accuracy and projection. These sources provide important information (regarding the existing of more than one branch on the Tagus delta, for instance) but the delineation of the features therein should be regarded as an approximation. Therefore, the maps for 12,000 BP, 4,000 BP and 1000 BP should be interpreted as well-informed approximations, rather than accurate depictions. For San Francisco Bay, we analyzed historical maps such as Cañizares (1776), Duflot de Mofras (1844), Cadwalader Ringgold (1850), Britton & Rey (1874), as well as landscape reconstructions such as Anderson (2013a, 2013b), which provide valuable information on the status of the estuary before and at the onset of European settlement. We also drew upon reconstructions of past geography and bathymetry by Schoellhamer (2013), Kirwan (2011), Goals Project (1999), Watson (2013), Atwater (1977, 1979), Wright (2004), Okamoto (2011), and Knight (2014), which provided information on the patterns of post-glacial flooding of the estuary, and the emergence and expansion of wetlands. For the Tagus estuary, we analyzed prior studies of historical change and paleostratigraphy (especially the exceptional work of Vis (2008), but equally with inputs from Martins (2010), Schriek (2007), Leorri (2013), Dias (1997), Fletcher (2007), and Uribelarrea (2003)), and complemented them with the abundant information provided by historical maps (such as Seco (1561), Gendron (1757), Eça (1767), Cabral (1790), Costa (1809 and 1813), Lamotte (1821), Silva (1847), Lopes (1930, 1945), and Instituto Hidrográfico (2012)), and historical documentation of land-use (Companhia das Lezírias 1839). We used historical data compiled by Beirante (1998), Madaleno (2006), Soares (2011), and studies of historical and modern distribution of wetlands (Vale 1987, Gameiro 2007, Ribeiro 2003, Taborda 2009). Additionally, we combined map data from NASA (2010), Goals Project (1999), USGS (2006) and IGP (2007) with the information on wetland distribution from the previous sources in mapping the current situation.

Each reconstruction was assembled as a project in GIS software and we retrieved the area of each of the following categories: *permanently flooded*, corresponding to open waters of the estuary; *wetlands*, corresponding to the extent of mudflats, oyster , and saltmarsh; *drained for farmland* corresponds to the conjectural extent of wetlands and permanently flooded areas that were converted onto farmland; *diked ponds* is the area of former wetlands and open waters that were diked for the creation of salt ponds; and *landfilled for urban development* corresponds to those areas of landfill which were developed as large infrastructure (such as ports, airports, transport and other infrastructure corridors, refuse disposal), industrial, commercial or residential areas. From these values, we created chronograms tracing the relative percentage of each category in relation to the maximum extent of estuarine lands before disturbance (corresponding to the scenario for ~4,000 Y.B.P.).

	Lisbon		San Francisco	
	Maps	Other documents	Maps	Other documents
12000 Years Before Present (Figs 2a & 3a)	**Dias 1997**, Vis 2008	Schriek 2007, Leorri 2013, Fletcher 2007	Atwater 1977, **Atwater 1979**	Smith 2011, **Okamoto 2011**, Barnard 2013
4000 YBP (Figs 2b & 3b)	**Vis 2008**, Dias 1997, Taborda 2009, NASA 2009	Schriek 2007, Leorri 2013, Fletcher 2007	Atwater 1977, **Atwater 1979**	Smith 2011, Barnard 2013, Goman 2008, Okamoto 2011, Anderson 2013b
1000 YBP (Figs 2c & 3c)	**Seco 1561**, Gendron 1757, Eça 1767, **Vis 2008**	**Beirante 1998**, Martins 2010, Fletcher 2007	Watson 2013, Atwater 1979	Goman 2008, Barnard 2013, Kirwan 2011, Watson 2013, Anderson 2013a and 2013b
ca. 1800 (Figs 2d & 3d)	Gendron 1757, Eça 1767, **Cabral 1790**, Costa 1809 and 1813, Lamotte 1821, Silva 1847, Vis 2008	**Martins 2010**, Peixoto Matias 2010	**Goals Project 1999**, Duflot de Mofras 1844, Atwater 1979, Watson 2013	Kondolf 2008, Swanson 1975, Anderson 2013a and 2013b
Developed landfill and 20th century projects (Figs 6a &6b)	Silva 1847, **Lopes 1930** and 1945, COS 2007, Instituto Hidrográfico 2012	**Costa 1999**, Duarte 2013	Watson 2013, **BCDC 1998**	Kondolf 2008, **Swanson 1975**
Current Situation (Figs 1a, 1b, 2e & 3e)	**COS 2007**, Instituto Hidrográfico 2012, NASA 2009, Vale 1987, Ribeiro 2003, **Gameiro 2007**, Taborda 2009	Martins 2010, Duarte 2013	**Goals Project 1999**	Kondolf 2008, Swanson 1975

Table 3 – Sources used for the reconstruction of environmental histories.

2.2.2 Analysis of planning literature and legal documents

We reviewed past and current legal standards, contained in laws and planning documents, and compared them with historical land-use changes. This allowed for a critical analysis of the historical adherence and detach between theoretical planning standards and the actual outcomes in terms of land-use changes, especially regarding reclamation, expansion of landfills and shoreline development. For historical law doctrines and standards our main sources for the Tagus Estuary were Beirante (1998), which lists a number of precedent-setting court decisions predating the mid-1800s Portuguese Civil Code (including King John I v. Gonçalo Velho (1410)), and Cândido de Pinho (1985). For more recent standards for the definition of the Public Domain and delimitation of the high water line used in its definition, we referred to Rilo (2014) and Assembleia da República (2005). The later also provides indication of the current doctrine regarding erosion & avulsion. Moniz (2011), and APA (2013) document the Tagus Estuary Management Plan's regulation and objectives, and are complemented by recent news regarding environmental standards and enforcement of Public Domain law (Garcia 2014, Soares 2014). For the SF Bay, we consulted references on the Public Trust Doctrine (Sax 1970, Lazarus 1985, Eichenberg 2009, 2013, Cech 2010, McGinley 2013, The Crown Estate n.d.) and complementary information on the doctrine regarding erosion & avulsion (Ruggiero 2001, Caldwell 2007, Sax 2009, Glasscock 1993). We also analyzed documents regarding the specific institutional and legal arrangements around the San Francisco Bay (Dolezel 1971, Luken 1974, Briscoe 1979, City of Berkeley v. Superior Court 1980, Davoren 1982, Berke 1983, BCDC 2011, Johnson 2013).

2.3 Results

2.3.1 Environmental histories of the estuaries

The Tagus Estuary

The Tagus Estuary was created after the end of the last glacial period, when the rising sea level drowned the lower Tagus River valley (Dias 1997, Vis 2008). After being drowned by the rapid post-glacial sea level rise, the inland delta of the Tagus grew through sediment deposition, and sediment further accreted along the margins of the estuary, establishing tidal wetlands.

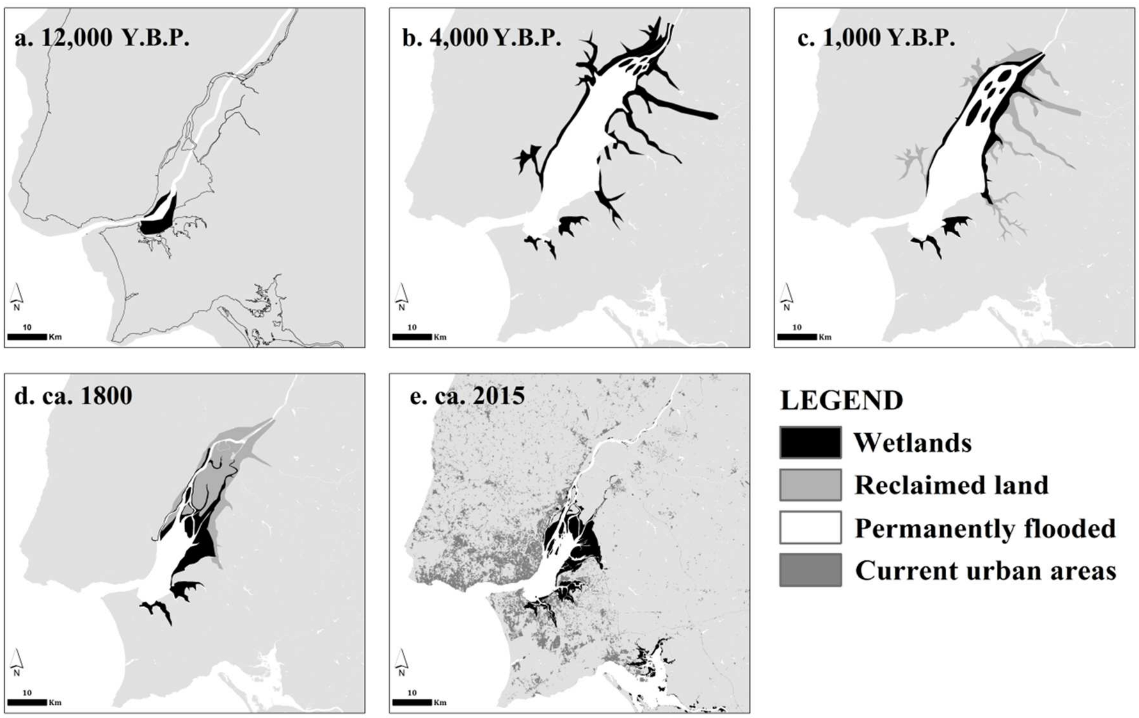

Figure 4 – Environmental history of the Tagus Estuary: a) situation of the narrow estuary ~12,000 Years Before Present, following the Last Glacial Maximum; b) ~4,000 Y.B.P., after the rate of SLR stabilized, the estuary began to fill, and wetlands became established at sheltered and upstream sections; c) ~1,000 Y.B.P., after at least one millennium of settlement around the estuary and along the basin, increased sediment inflow and prograding delta, with reclamation already occurring along tributaries and margins on the upper delta; d) ca. 1800 most of the reclamation of the delta and consolidation of the lezírias was complete, but the river still displayed remnants of its former anastomosing delta; e) Current situation. Wetlands are now mostly confined to the widened middle section of the estuary, and the remnant river branches have been transformed into regulated irrigation channels. Urbanization and infrastructure has taken over most of the right bank along Lisbon, Oeiras, and some south bank municipalities. Along the eastern edge of the estuary, the largest expanse of mudflats and marshes is set against farmland, with very limited urban development. The South Bank hosts small but important marshes, heavily encroached by urban development.

The evolution of wetlands and settlement around the Tagus estuary was one marked by repeated cycles of reclamation of the coastal prairie that formed behind the advancing ("prograding") pro-delta situated at the upstream section of the estuary; as the frontline of mudflats and saltmarsh accreted and moved downstream, it created behind it a large floodplain of fertile soils, which were seized and used for agriculture by all the successive civilizations that controlled it, from the Romans to the Visigoths, on to the Moors and, eventually, the Portuguese. This special kind of low-land, reclaimed farmland, traditionally protected by low walls or stakes, along the lower Tagus valley, is called the "lezíria". The term derives from the Arabic *al-jazīrah*, meaning island, and referred to depositional islands, point bars, and tidal flats along the river channel. Later, it came to be synonymous with the alluvial plain as a whole.

Although accurate descriptions of the estuary are lacking before formation of the Kingdom of Portugal in the mid-12th century, some documents hint that there was already a practice of draining the *lezírias* for farmlands before then (Beirante 1998, Schriek 2007). The modification of the watershed and virtual extirpation of primeval forests was completed before the end of the Middle Ages (Fletcher 2007, Uribelarrea 2003), resulting in greater influx of sediment onto the estuary, which likely accelerated the rate of wetland expansion and extent of potential *lezírias* farmland (Figure 4c).

The Tagus went through periods of avulsion of the main channel (natural process through which the river abandons a channel and switches to another) and, by the late middle ages, there were at least three channels running parallel, with two of those preserved as navigation canals running parallel to the main course. Historic names for branches, or arms, in the lower Tagus - *Tejo Novo* (New Tagus), *Tejo Velho* (Old Tagus), *Tejinho* (Little Tagus) – indicate that its anastomosing nature lasted until relatively recently (Beirante 1998: 774, Martins 2010: 27) and this is reproduced in some historic maps. No defined main arm is indicated on the map of Seco (1561), and the "Old Tagus" is still identified on maps as late as the 18th century (Eça 1767, Cabral 1790, Lamotte 1821), showing at least some clearly natural arms of the river running into what is now the Lezíria Grande island, and showing that there was at least partial retention of some wetland habitat along the margins of those channels (Figure 4d).

Historical records, such as those presented in Beirante (1998) and Madaleno (2006), indicate that expansion of farmland through land reclamation was done through cycles of great commitment, usually encouraged by more enterprising kings (more land reclaimed, and greater yields, equaled more taxes). These periods of intense reclamation followed others of relatively lax central power and/or lack of workers and funds (periods of war, "bad" kings…), during which flood defenses fell into disrepair, and changes to the estuary's hydrology due to deforestation, avulsion of the river's channels during floods, or fluctuations in sea level and storminess during the Medieval Warm Period and the Little Ice Age. Protecting farmland against floods and high tides required the construction and constant maintenance of protective walls, and insuring the navigability of the river, was a constant struggle (Martins 2010).

The most extensive efforts of landfilling for infrastructure were related to the expansion of the Port along Lisbon municipality's waterfront, between the last couple of decades of the 19^{th} century and the first three decades of the 20^{th} century (Durão 2012). In total, some 397 ha of fill were created along the already urbanized waterfront, mostly within the Lisbon municipality. In the mid-20^{th} century, some areas in the south bank of the estuary were landfilled for the expansion of large industrial units and port areas (notably the Quimiparque grounds, in Barreiro, the Lisnave shipyards and Alfeite naval base, in Almada, and the Siderurgia Nacional complex, in Seixal) but together these areas amounted to only about 236 ha. A further 36.8 ha of localized expansions to pre-existent port areas were added in the first decade of the 21^{st} century. In total, landfilling for purposes other than farming was less than 670ha. Industrial areas and large infrastructure occupy virtually all those areas, with only negligible residential and commercial development. A 1950s plan to create a large dyke and bridge between Lisbon and Montijo would have presupposed the reclamation of as much as 8,000 ha of marsh and mudflats for the expansion of the irrigation project (Figure 8a). Fortunately, the project was postponed and definitively abandoned for environmental reasons in the 1970s (Costa 1999: 41).

Since the mid-20th century, dams along the mainstem Tagus (in Spain) and on tributaries (Spain and Portugal) have extirpated anadromous fish runs of more sensitive species (Batista 2012), significantly reduced the inflow of fresh water onto the lower estuary, and reduced the sediment loads dramatically to as little as 1/3 of its prior level (Andrade 2002: 187). Nevertheless, the Estuary still appears to have a positive sediment balance, with progradation rates of around 1.1 cm/yr (Costa 1999:33). Studies conducted on the Estuary's marshes estimate that the current sedimentation rates (4 to 27 mm/yr, depending on the location) will allow wetland accretion to keep pace with the rates of sea-level rise predicted for the end of the 21^{st} century (Duarte 2013, Silva 2008, Silva 2013).

The estuary's water quality was severely compromised by untreated industrial and sewage effluent, with severe impacts on the estuarine ecosystem (Costa 1999, Caçador 2001). At the turn of the 21st century, the situation improved substantially: the closing down of major industries and a major program to introduce primary and secondary sewage treatment along the Tagus river basin, spurred after Portugal and Spain's accession to the EU in 1986, allowed a slow but steady improvement in water quality, increased fish stocks, and the return of some sensitive species (Costa 1999: 164, Soares 2011, Duarte 2013).

The San Francisco Bay

During Pleistocene time, what is now San Francisco Bay was an alluvial plain, across which flowed the lower Sacramento River, joined by its many tributaries. The rise in sea level after glacial melting led to the flooding of SF Bay, reaching approximately its current extent ~5,000 Y.B.P. (Atwater 1977), and slowing to a rate of about 20cm/century. The estuary began slowly filling with sediment (from tributaries and the mainstem Sacramento), resulting in the fixation and slow expansion of wetlands from around 4,000 Y.B.P. (Barnard 2013, Goman 2008) with a slightly accelerated expansion during the Little Ice Age (ca. 1550 to ca. 1850) (Watson 2013) due to land cover changes in the watershed (Anderson 2013 a, 2013b).

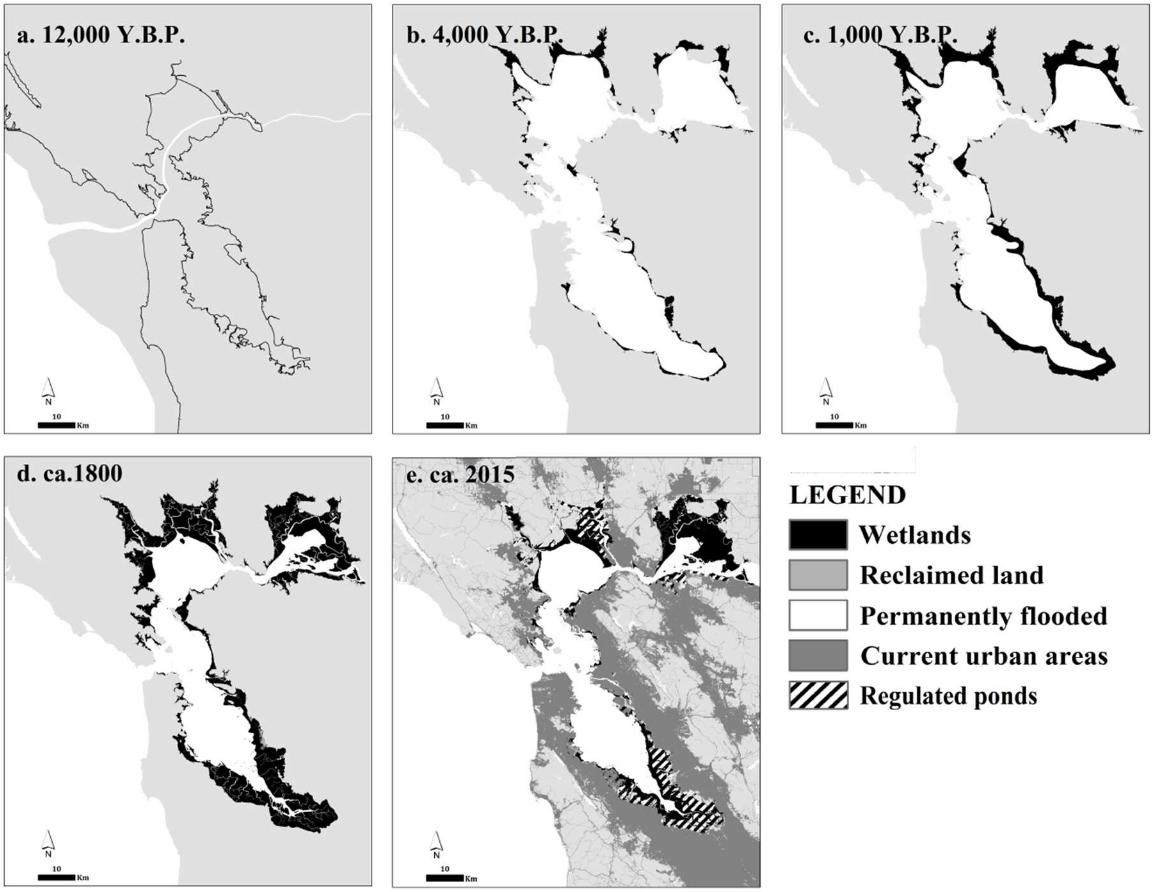

Figure 5 – Environmental history of the San Francisco Bay: a) Around 12,000 Years Before Present, with sea-level much lower than present, the narrow river channel emptied into the ocean near the Farallones Islands; b) ~4,000 Y.B.P., having filled the Bay after a few millennia of rates of SLR of about 2 mm/yr, the rate drops by ten-fold and allows wetlands to become established at sheltered and sediment-rich edges; c) ~1,000 Y.B.P., early human activity around the Bay and the Central Valley have influenced sediment input, but the pattern of slow accretion and expansion of wetlands persists; d) ~1,800 Y.B.P., grazing and changes to land cover upstream accelerate sediment deposition and wetlands expand rapidly; e) Current situation. After one century marked by much-accelerated deposition due to hydraulic mining, wetlands expand in the mid-1800s, only to be transformed along their edges into farmland, salt ponds, and urban areas. Especially along the South Bay and on the north edge of San Pablo Bay, vast areas remain diked to this day, but recent restoration efforts are converting most of the former salt ponds onto restored wetlands. Just upland from these ponds and remaining marshes, most of the farmland has been developed into commerce, industry, housing and infrastructure, encroaching upon most wetlands.

Around the time the first European settled around the San Francisco Bay, after 1769, the Bay was still a largely undisturbed natural environment. The few thousands of Ohlone Native Americans that had long lived around the Bay introduced changes to land cover, from controlled burnings and selective clearing, but likely had minimal impacts over the environmental performance of the larger estuarine ecosystems (Figure 5d, Okamoto 2011:108-111). For the most part, the natural succession of mudflats-low marsh-high marsh-coastal prairie was still present by the time of the first surveys (Goals 1999) and features prominently in some early maps of the Bay (Cañizares 1776, Duflot de Mofras 1844, Britton & Rey 1874). This latter element, the coastal prairie extending just above the highest tides, elusive as it is now around SF Bay, has likely been absent from the Tagus Estuary in historical times. Suffice to say, this readily-available provision of alluvial soils just high enough above the saltwater to allow cultivation was the first victim of large-scale settlement.

Encouraged by policies promoting the draining and filling of wetlands for agriculture, vast areas of tidal wetland were dyked and drained for farmland, from the 1850s onwards. From the late 1800s through the 1930s, vast areas of salt ponds were created at the expense of tidal marshes, with the largest salt-producing company, Leslie Salt, still owning over 21,000 ha of Baylands as late as the mid-70s (Luken 1974: 140, Okamoto 2011: 133). This was followed by extensive landfilling for large infrastructure, ports, industrial areas, and even residential neighborhoods, such that over 90% of the Bay's pristine tidal saltmarshes had been lost to dredging and landfilling by 1965 (Goals Project 1999, Williams 2001, Madsen 2007).

The process of reclamation was made easier by parallel changes set off by the introduction of hydraulic mining in the Sierra Nevada (1852-1884), which increased sediment loads of the Sacramento River ten-fold (Barnard 2013, Schoellhamer 2013, Wright 2004), causing rapid accretion of the shorelines and shallowing of the estuary, making it easier to dredge and landfill vast areas of the Bay's shorelines. Swanson (1975) estimates the rates of new landfill at ~414 hectares/year between 1850-1900, ~622 ha/yr between 1900-1925, ~751 ha/yr between 1925-40, and a high of 914 ha/yr from 1940 to 1965, the year when reclamation was effectively halted.

Well upstream from SF Bay, extensive 20th century construction of dams and water diversions in the Sacramento River basin resulted in reductions in fresh water inflows to SF Bay, blocked migration of anadromous fish, and trapped most of the natural sediment load before reaching SF Bay (Okamoto 2011: 138-144). From an estimated peak of about 10 Mt/yr, average yearly sediment loads from the Central Valley could be as low as 1-1.2 Mt/yr currently. In fact, now that most of the hydraulic mining debris has been mobilized all the way down to the estuary, Bay Area watersheds may currently be delivering more sediment to the Bay that the mighty Sacramento-San Joaquin system (Barnard 2013) and sediment yields may fall below pre-disturbance levels. If we consider the accelerated rates of SLR expected for the next centuries, the survivability of marshes may be in jeopardy (Orr 2003, Watson 2013), as their ability to keep pace with SLR through accretion is largely dependent on the suspended sediment load (Stralberg 2011, Swanson 2014).

In the late 19th and 20th centuries, the Bay became heavily polluted by discharge of untreated industrial and municipal sewage until the closure of many bayside industries and extensive construction of wastewater treatment plants following passage of the state's Porter Cologne Act of 1969 and the federal Clean Water Act of 1972 (Okamoto 2011: 158-160). Following the passage of the McAteer-Petris Act of 1965 (see next section), landfilling was halted. Wetland restoration efforts have ensued and, especially since the implementation of Bay-wide ecosystem restoration targets (Goals Project 1999), the purchase and restoration of several salt ponds has allowed for a steady increase in the provision of habitat (Williams 2001, Goals Project 1999, Kondolf 2008, Madsen 2007, Klatt 2013) That culminated in the ongoing South Bay Salt Ponds Restoration Project (SBSPRP 2014).

Comparison

Setting side-by-side the chronograms tracking the evolution of both estuaries, in terms of the relative percentage of each main category of land cover (Figure 6 a and b) it is apparent that, while the transformation of the Tagus lowlands has been much more extensive, former estuarine lowlands lost to urban development stands now at around 0.8% of the total, whereas 8.6% of the former San Francisco Bay lowlands have been transformed into urban areas.

The Tagus Estuary has experienced a much longer process of anthropogenic disruption, and its smaller size lent itself to faster infilling. Therefore, the net loss in open water surface, as compared to the baseline for the maximum extent of estuarine lands (approximately the sum of permanently flooded surface and wetlands for the ~4,000 Y.B.P. maps, Figure 4b and Figure 5b) was much greater in the Tagus than in SF Bay, which remained largely undisturbed until a couple of centuries ago. Compared to its reconstructed maximum, the Tagus Estuary has shrunk to about 27.8% of its mid-Holocene maximum, with most of the loss being attributable to millennia of progradation and consolidation of farmlands before the 1800s. SF Bay experienced an equally slow process of natural progradation, which led to the creation of extensive wetlands around its edges. All in all, about half of SF Bay's maximum extent is still permanently flooded.

From an environmental standpoint, the most relevant indicator would be the overall provision of wetlands and similar habitats around each estuary. The Tagus Estuary was allowed to developed extensive wetlands near its prograding delta has soon as the rate of sea-level rise slowed down. Nevertheless, as this process has been coupled with disruption from human activity for at least the last two millennia, the natural process of wetland expansion was curbed by a simultaneous reclamation of higher ground, contributing to a slow decrease in total area of wetlands. Although significant, we reconstruct this reduction to be no greater than half the maximum extent of wetlands (~290 Km^2 to ~144 Km^2). From our reconstruction of the estuary's environmental history, wetlands may have represented around 35% of total estuarine area (~290 Km^2) around 4000 BPY, but have stabilized at around 20% (~145-150 Km^2) throughout the last millennium and stand currently at ~144 Km^2 (~18% of total estuarine area).

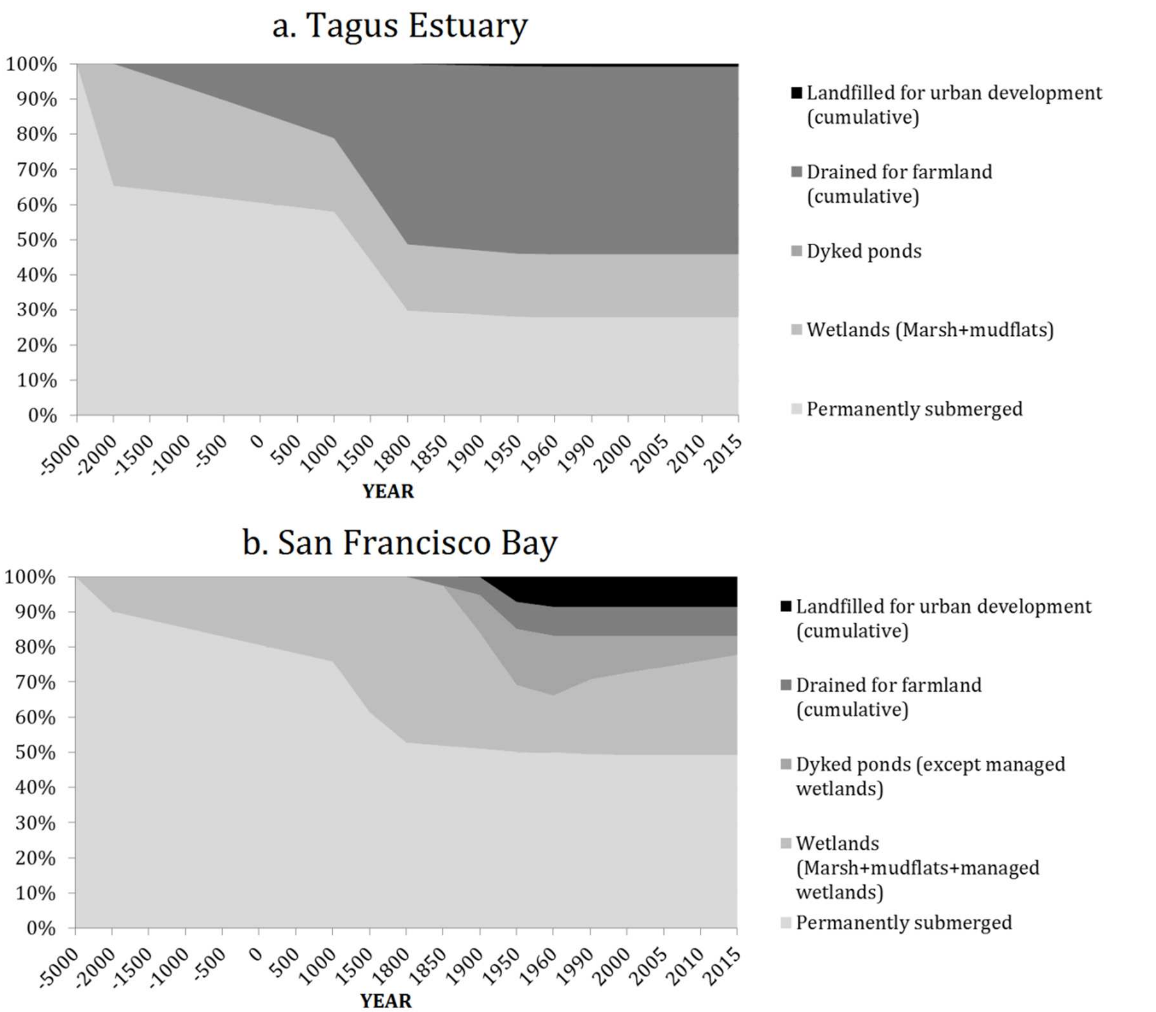

Figure 6 – Chronograms tracing the evolution of land cover in estuarine low lands of the Tagus Estuary and San Francisco Bay (relative %).

The San Francisco Bay experienced a mostly undisturbed natural process of progradation from around 4,700 Y.B.P.. with a slow expansion of wetlands and parallel reduction of permanently submerged area This trend accelerated and slowed down through a series of loops and feed-backs between regional trends in rainfall and smaller fluctuations in global sea-level (Watson 2013). With the arrival of European settlers, in the mid-1800s, the expansion of wetlands is believed to have accelerated with the increased sediment deposition, first with land cover changes produced to the Sacramento-San Joaquin watershed from the 18th century onwards, and especially during the period of hydraulic mining of the late 1800s (Schoelhammer 2013). After a steady increase in total area of tidal wetlands, reaching a maximum of around 994 Km^2 (about 47% of the total estuarine area), the subsequent landfilling and draining led to a very rapid decrease to ~700 Km^2 (~33%) around the turn of 20th century and as little as ~340 Km^2 (~16%) by the mid-1960s. After early experiments in wetland restoration, large efforts in restoration, focusing especially in the reversion of salt ponds into managed wetlands, have increased significantly the total provision of tidal or managed wetland provision around the Bay, from the 1960s low-point to about ~475 Km^2 (22,6%) in 1998 and nearly 600 Km^2 today, close to the Goals Project (1999) target of about 615 Km^2.

2.3.2 Legal Context

The differences in tidal wetland conversion and lowland urbanization patterns between Lisbon and San Francisco estuaries can be largely attributable to their different legal traditions and contexts, as we analyze ahead.

Lisbon and Portuguese Law

Grounded on a legal tradition that can be traced back to at least the 6th century with the Justinian Code, navigable waterways (and, to a lesser extent, their margins) have enjoyed legal protection under the assumption that they should to be preserved for the common good. Although not always explicitly stated, for most of history this was more a mechanism to ensure the Crown or the State's ability to control, and tax, waterborne commerce and fishing.

The doctrine regarding erosion and avulsion may be equally old. Once the river experienced avulsion, typically during larger flood events, abandoned channels or islands suddenly connected to the margins. In times when the centralized power was weakened, local municipalities, religious orders, or even neighboring landlords would often seize the newly-created land. There is ample documental evidence of the efforts made by several kings in asserting their ownership over those lands, the "lezírias", and Beirante (1998) argues that this struggle marked a defining moment in the affirmation of centralized power in the early centuries of the Kingdom of Portugal.

The long-standing practice of preserving a fringe of wetland is consistent with the practice of reserving all land below "the December High Waters" for the Crown (that is, in Public Domain), a measure grounded on the old Roman tradition of a public trust protecting all navigable waters and floodplains (Cândido de Pinho 1985).

In 1864, all shores subject to inundation at spring-high tide were designated Public Domain (Royal Decree of December 31st, 1864). Some 30 years before, the *Companhia das Lezírias*, then a private society, was created to manage the farmlands belonging to the Crown Prince. The model of public-led management of the bulk of farmland located on the alluvial plain persists to this day, and has largely prevented extensive urbanization of these productive agricultural lands.

Major reclamation efforts would traditionally follow either major flood events or periods of abandonment. Faced with the Crown's inability to single-handedly restore all productive land, the king would often stimulate the rebuilding of flood defenses and retaining walls by granting temporary deeds to those willing to drain, defend, and farm the land. From the omnipresence of references to "swamps", "beaches", and "wastelands" throughout historic documentation, it is clear that, even during the periodic spurts of reclamation, a fringe of lower marsh was present. As elsewhere in Europe, the navigable waters and shorelines constituted public trust owned by the

Crown, and unwarranted alteration or appropriation by private citizens was often the subject of legal action and generally forbidden.

One particular document, from the early 15th century, is most enlightening in this respect and indeed produced jurisprudence that carried continuously into present Portuguese law. King John I (1385-1433) had been, in the first decades of his reign, particularly active in asserting his right to all swamps and "lezírias". At first, he resorted to the traditional Visigoth concept through which "terras ermas" (wastelands or abandoned lands) belonged to the Crown. In 1410, however, the King successfully argued in the Crown's Court that a landlord had illegally occupied land (a beach located on the banks of the Estuary) that was his by right resorting to a novel legal mechanism: the river *and its banks* were both "public in nature" and that the property (a beach) was once "lezíria" and all "lezírias" were his by right (King John I v. Gonçalo Velho 1410). The doctrine invoked by the Court to rule for the King explicitly stated that since the property (was) fully covered with water in January (that is, during the largest floods), and only dry during the Summer, it indeed belong to the Crown's Estate. That Court's decision established precedent on two crucial aspects: 1) river banks subject to flooding are to be included in the Crown's Estate as part of the *Jus Publicum*; 2) for that purpose, the highest elevation of floods is to be considered – the "January high waters". This decision restored onto common doctrine the old Roman tradition of "Public Right" (*Jus Publicum*) to flood-prone beds and banks.

Through different legal ordinations, these standards were preserved and, according to the fluctuations in the effectiveness and power of the central administration, more or less upheld. Eventually, these *Jus Publicum* (corresponding roughly to the American concept of Public Trust) determinations were codified into the modern civil code (Código Civil) after 1864. The "Domínio Público", or Public Domain, as this doctrine came to be known in Portugal, was then expanded to include a 50m buffer inland from the high-water mark in coastal waters where only deeds predating the creation of the Law would be permitted and all new construction or land use transformation would be severely conditioned. This expanded jurisdiction over margins was quite innovative at the time and remains one of the most generous in Europe (Andrade 2002:179). In the subsequent 150 years, the Public Domain remained a staple of Portuguese land law and has arguably been the strongest mechanism for the protection of coastal resources, the preservation of wetlands, and maintaining public access to the country's shorelines.

Among the provisions in the new environmental law, there has been a refinement and expansion of the protection granted to natural systems, and wetlands now have specific articles protecting them from destruction or alteration. Wetlands, and all floodplains, have specific protection under the National Ecological Reserve (Decreto-Lei nº321/83), but coastal wetlands were, by definition, already included in the Public Domain. Further expansion of the protective buffer inland from the dominial waters came with the new Water Law (Assembleia da República 2005) which matured from earlier legislation the concept of "adjacent zones" in flood-prone or sensitive areas, extending a limited planning mandate over all land considered as vulnerable to flooding from river or sea waters.

In the specific instance of waters under tidal influence, as is the case with the Tagus Estuary, the effects of wave run-up are also to be considered as forcing factors when defining the "highest astronomical tide line" (HAT) that serves as the upper limit for the "bed". In the case of the Tagus Estuary, the Governmental Decree authorizing the Environmental Agency to elaborate the Estuary Management Plan (APA 2013), established (according to the concept of "adjacent zones") a planning mandate for a 500m transition zone inland from the upper limit of the Public Domain, which already includes the 50m-wide "margin" (Figure 7). Furthermore, the national law establishes that "land lost to the sea" through erosion is to be automatically incorporated into the Public Domain, and the adjoining buffers realigned according to the new shoreline.

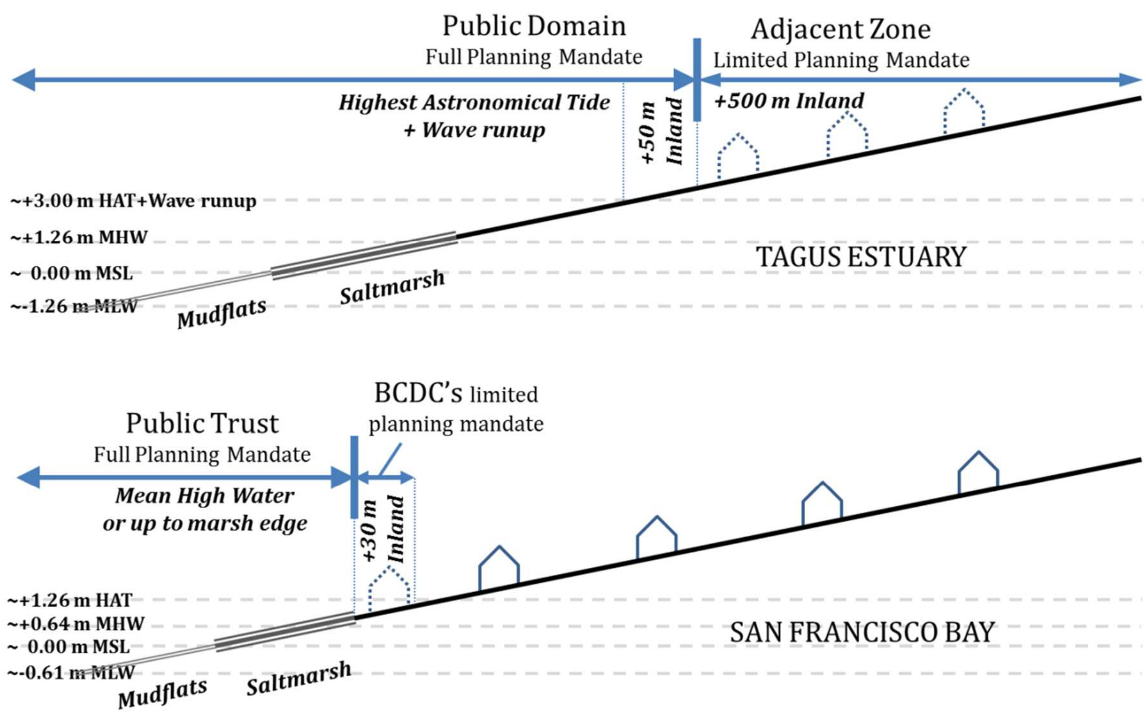

Figure 7 – Definition of Public Trust/Public Domain and additional planning mandates in the Tagus Estuary and the San Francisco Bay.

San Francisco and United States Law

The United States inherited several fundamental doctrines dating back to Medieval English Common Law. Among these is the doctrine that preserves the "Jus Publicum" (the "Public Right") over navigable waters and flood-prone banks and shorelines. They are "held in trust" by the State, hence its modern denomination as the Public Trust Doctrine. It corresponds to the concept of Foreshore (United Kingdom), trusted to the Crown's Estate. The Common Law dispositions are themselves distant derivatives of much older doctrines, and in particular the same Roman Justinian Laws, themselves derived from yet older legal codes (Cech 2010: 250-255, Slade 1997: xii, 1, 3-5). The aim of this doctrine, as in Portugal, was to preserve natural resources for the common good (albeit through the upholding of the monarch's right to control and tax all uses and foreshore concessions…). The letter of the law includes, for most countries with a Common Law tradition, a variation of the notion that all navigable waters and lands that are subject to regular flooding (that is, those located below the high water line) are to be preserved for the public (Lazarus 1985, Eichenberg 2009, Titus 1998, Sax 1970, Slade 1997). So, in essence, this is a similar concept to that of the tradition of most European countries, of which the Portuguese Law is an example.

The peculiarities of its practical application, however, derive from the early decision of American legislature to grant this Trust onto the States, which in turn led to significant differences between different States' interpretation and jurisprudence. The Federal Arkansas Swamp Lands Grant Act (1850) made appropriations of "swamp and overflowed" lands a prerogative of the individual states. California promoted draining and filling of wetlands for agriculture, as a way of attracting settlers to the newly-created State. Importantly, it granted full property titles, rather than temporary concessions, over reclaimed land, a solution that would later be determined as in violation of the prerogatives of the Public Trust, over a century later, as will be discussed further ahead. Between 1855 and 1909, "land" (more often than not, marshes subject to twice-daily flooding) was sold at auctions for as cheap as $1 per acre (Luken 1974). The extent of this state support for wetland draining and landfilling is reflected in the Reclamation Map of 1874, showing all wetlands and most shallow flats as subject to reclamation (Britton & Rey (1874), reproduced in Woodbridge (2006)), and even a 1959 US Army Corps map that showed all shallow waters as potential landfill (reproduced in BCDC (1998: 4) and included in Figure 8b).

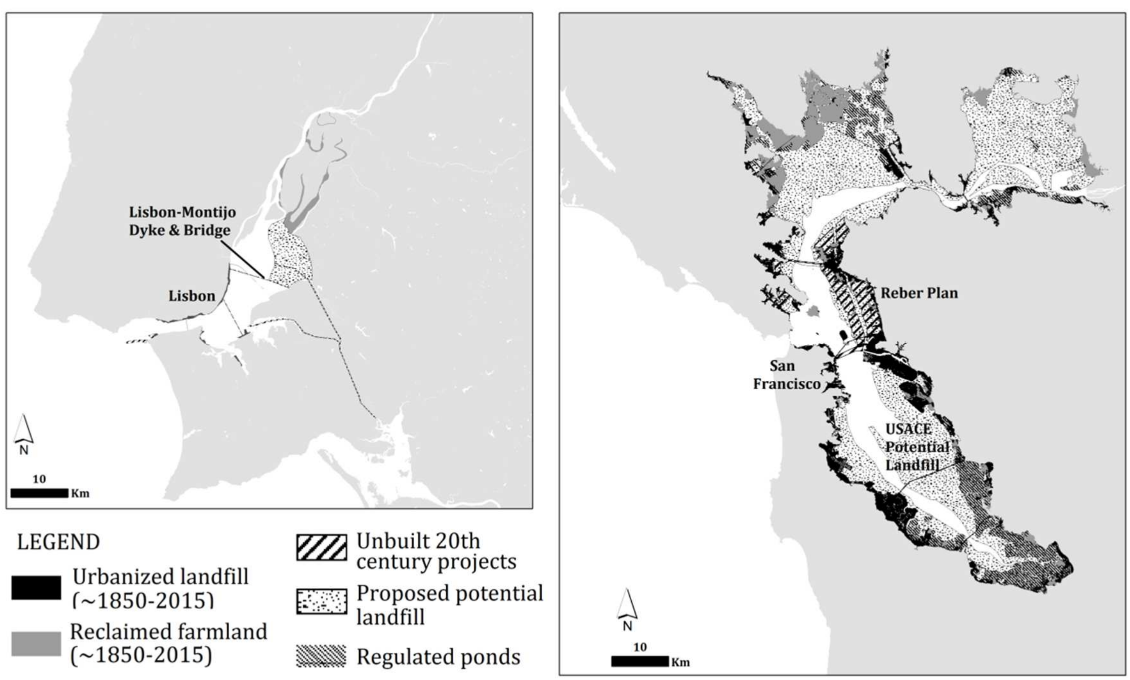

Figure 8 – Urbanized landfill, reclaimed farmland, and cancelled projects (~1850-~2000).

Another state prerogative was the definition of the landward limit of the Trust. In shorelines subject to tidal action, the definition of the "high water", which is crucial in bounding the upper limits of the Trust, is defined by most US States (including California) by the high water mark (Slade 1997: 6-8). For most purposes, the Mean High Water (MHW) is considered. It corresponds to the average of all high tides of each tidal day during a 18.6-year Astronomical Cycle. This means already that the Portuguese Public Domain extends its protection up to a greater elevation, and thus typically extends further inland than the Californian Public Trust (Figure 7).

In a legal context more favorable towards the upholding of individual property rights over common good interests than in most of Europe, the expansion of planning mandates and the upgrading of environmental law and planning standards has proved more difficult. This is especially true whenever these new provisions would entail the imposition of restrictions over the use of private property. In the absence of systematic evolution of planning and environmental law to adjust to changing social paradigms and expectations, as was mostly the case in countries belonging to the European Union, the Doctrine has been used as a proxy for strong environmental legislation and, since the 70s, it has served as a legal loophole of sorts in natural resources preservation (Sax 1970). This has led to some criticism over the unnatural expansion of its scope well beyond the common water resources it initially aimed to protect. The Public Trust Doctrine has been invoked in cases involving cemeteries, air resources, or in implementing a State's hazardous waste control legislation (Lazarus 1985) to the point where it became almost a moniker for public interest in the protection of natural resources.

The dramatic alteration from natural shorelines to landfilled and dredged urbanized waterfronts, and even more the threat to completely fill SF Bay as envisioned in the Reber Plan (Price 2002), had a deep impact on the public and institutions in the SF Bay region. The Reber Plan's proposal to fill-in SF Bay, except for a narrow ship canal, and the ensuing "potential landfill" studies by the US Army Corps (Swanson 1975, BCDC 1998: 4) shocked many into realizing that such a large and iconic ecosystem could come under real risk as a result of reckless development decisions (Figure 8b). Grassroots movements garnered support for the McAteer-Petris Act, passed by the California legislature in 1965 (Walker 2009). It led to the creation of the San Francisco Conservation and Development Commission, the first coastal zone management agency in the United States (Swanson 1975). BCDC was tasked with the elaboration of the Bay Plan, and gave it full planning powers over areas subject to tidal action (mean high water or, in tidal marshlands, the inland edge of marsh vegetation up to five feet above Mean Sea Level). In practice, it was extremely effective in curtailing all major efforts of wetland "reclamation" (Dolezel 1971), and it reasserted the State's right to protect all lands included in its Public Trust. An additional 100ft (~30m) buffer extending landward from the high water line was included in BCDC's jurisdiction, but with no planning mandate other than the ability to impose public access to the shores. Therefore, the Commission has a very limited capacity to prevent new development proposed just above the high water (Eichenberg 2013).

Paradoxically, the aforementioned extension of litigation over the Public Trust Doctrine well beyond its original scope has led to a legal backlash (already foreseen by Lazarus (1985)): while recently amending the Bay Plan (2009), the BCDC was confronted with resistance from developers and local governments in asserting its right to manage tidal lands (Johnson 2011). BCDC had to assert that their mandate extended over Bay shorelines up to the limit of the Public Trust, the MHW, and therefore encompassed all tidal lands (Eichenberg 2009, Travis 2009). This added difficulty in expanding mandates and jurisdictions of public agencies is by no means new, and has been a recurring problem for Bay Area planners (Davoren 1982, Eichenberg 2013). Given the difficulty in ensuring their current mandate is respected and acknowledged, a near-future expansion of its planning mandates (so as to incorporate meaningful buffers upland from this limit) is unlikely and prone to intense litigation

Nevertheless, being that the Doctrine is tied to a concept of "high water line", rather than an actual demarcation, it is now perceived as a plausible mechanism of SLR adaptation, especially once coupled with another ancient doctrine regarding erosion and avulsion (Sax 2009, Titus 1998, Glasscock 1993). Combined, they would read as follows: in episodic erosion caused by natural events or through unforced flooding by river or sea waters, land lost to the waters would automatically incorporate the Public Trust. The high water line would accordingly migrate landwards, and so would the jurisdiction of public agencies, without the need to resort to a typically traumatic takings clause. This is sometimes called a "rolling easement" (Titus 1998, 2011) and provides a solid legal basis for BCDC to invoke the "ambulatory nature" of its jurisdiction (Eichenberg 2009: 263).

2.4 Discussion

2.4.1 Property and land use in estuarine lowlands

The King's Lands were, in the specific case of the Tagus Estuary, granted to the Crown Prince's Estate, and remained so throughout the Middle Ages and until 1836, when the unified "Herdade do Infantado" (Prince's Estate) was sold off, in 1836, to a single corporation, the Companhia das Lezírias. Albeit promoting new irrigation projects and completing the draining of the Lezíria Grande (the large island that was created through the consolidation and unification of several former delta islands), the Companhia das Lezírias kept is focus on agriculture and grazing. Nationalized again in the 70s, this public company manages to this day the farming on the delta, and several species have adapted to forage or shelter in the farmlands. Most of the land remains in public ownership and transmission of full property rights was limited. It remained so until the introduction of modern legislation specifically protecting the best soils and floodplains. The result was that most of the lowlands around the estuary remained construction-free, first through the Crown's preference to promote profitable farmlands, helped by the frequent reminders, through major flood events, of the active nature of the floodplain, then through legislation specifically protecting the wetlands and farmland.

Around SF Bay, the Arkansas Act of 1850 was used by the State as a means to promote extensive draining and landfilling. Until the early 20th century, the titles to the "lands" were sold in auction, and the buyers were granted full ownership of the land. This was justified based on the need to create new farmland and attract settlers. Later, through the transmission to local city governments, the situation went from bad to worse. While initially this transference was destined to promote infrastructure improvements, most cities were unable to resist the profitability inherent to the transformation of wetland to "fastland", resulting in as much as a 75-fold increase in land value (Luken 1974). Vast areas of former tidal lands were therefore transferred onto private landowners, a practice that is clearly at odds with the principles of the Public Trust Doctrine (Briscoe 1979, City of Berkeley v. Superior Court 1980) and, as a consequence, the first half of the 20th century saw large expanses of former wetlands transformed onto salt ponds, industrial land, large infrastructure and, eventually, even residential areas.

2.4.2 Environmental protection standards and the concept of "high water line"

Around the Tagus, Roman doctrine regarding the protection of public waters has been enforced, with varying degrees of effectiveness, since the first half of the first millennium. It was upheld through a sequence of legal disputes, in the first centuries of Portuguese nationality (12th-15th century) and was clarified during the reign of King John I, with the 1410 Crown Court's ruling that reasserted the Crown's right to all lands subject to regular flooding by the "December High Waters". This standard would translate to today's Portuguese standard, which is the "Highest Astronomical Tide Line" (HAT) (Rilo 2014). This corresponds to the exceptional elevation of waters during the Equinoctial Spring Tides, that is, the largest tides of the year.

In contrast, the same Roman legal code was transferred onto English Common Law and later into US law, with several important distinctions. The most relevant of which would be the interpretation of the "High Water Line", which delimits the Public Trust. Already present in British legal standards (with the exception of Scotland, which upholds the higher Mean High Water Spring standard), the High Water is considered in most US states, including California, to correspond to the Mean High Water (MHW) in coastal regions. MHW corresponds to an averaging over a 18.6-year lunar cycle of all the high tides of each day. The subtle distinction between adopting an "average" high tide or an "exceptional" high tide has important implications over the level of protection granted to coastal wetlands and the ability to prevent development in very low-lying land. As an example, the Mean High Water in Lisbon is ~0.86 m below the Highest Astronomical Tide (HAT) standard (Antunes 2011). Such a difference in elevation can extend dozens of meters across flat shorelines, and represent the difference between including all beaches, wetlands, and adjacent shorelines or excluding a significant portion of these. Additionally, the Californian Public Trust was complemented, specifically in the SF Bay, by a very limited planning mandate (addressing mostly provisions for public access) over a buffer strip 100ft (~30m) wide granted to the BCDC. Therefore, any development proposed immediately above the MHW may theoretically receive the go-ahead from city planning commissions. In contrast, the already generous Portuguese definition of the high water line is further reinforced with a full public planning mandate over a 50 m buffer inland from the HAT. Together they form the core of the Portuguese Public Domain, which is complemented by a limited planning mandate for an adjacent zone extending another 500m inland. In practice, outside existing urban perimeters, no further development is likely to receive approval according to the new Tagus Estuary Management Plan (APA 2013).

Both legal codes include provisions regarding erosion and avulsion (again, derived from very old doctrines, which may be traced back to at least the Justinian Code). The Portuguese Water Law of 2005 (Assembleia da República 2005) specifically mentions that all land lost to natural processes of erosion or flooding, including those potentiated by rising sea levels, is to be automatically considered to integrate the "bed" of rivers and sea shorelines, and the Public Domain provisions accordingly realigned. In the US, similar provisions deriving from the Common Law presuppose the inclusion in the Public Trust of land lost to erosion (Eichenberg 2013). In both estuaries, the end of landfilling, the steady creation of natural reserves, parks and refuges, as well as the recent introduction of more environmentally-friendly dredging practices (LMTS 2001, BCDC 2011, APA 2013) have contributed greatly towards the protection of existing wetlands and permanently submerged habitats.

The water quality in the Bay has been steadily improving since the application of state (1969) and federal (1972) laws regarding waste water treatment (Okamoto 2011: 158-160). The Tagus Estuary followed suit, albeit with a couple of decades' delay: waste water treatment was mandated across the whole Tagus river basin as Portugal and Spain complied with the European Urban Waste-Water Directive (91/271/CEE Directive) of 1991 and subsequent provisions. At the estuarine level, the conclusion of the related integrated waste water management system, accompanied by the relocation of heavy industries, led to water quality improvements over the last two decades.

Despite the long sequence of anthropic impacts, both estuaries remain very important natural habitats, and both are recognized as Ramsar sites of international importance along major flyways (McLusky 2004, Costa 1999). With water quality becoming less of a problem, the medium- to long-term strategies of dam removal, or at least the integration onto existing dams of functional fish passages (Cech 2010:428-435) and other measures, may in time allow the return or stabilization of anadromous fish stocks, and allow for a more sustainable sediment management (Kondolf 2000, 2014). This later aspect would likely be of crucial importance in enhancing wetland resilience in face of the increased rates of SLR, expected towards the end of the century, as the sustainability of wetlands appears to be strongly connected with the maintenance of a good sediment supply (Orr 2003, Watson 2013, Stralberg 2011, Swanson 2014, Duarte 2013, Silva 2008, Silva 2013).

2.5 Conclusion

Both estuaries share similar physical settings, have been affected by synchronous fluctuations in eustatic sea levels, and are located in mediterranean climate zones. The Tagus estuary has experienced continuous human settlement and progressive transformation of natural systems throughout over 2 millennia. The process of transformation of wetlands onto farmland was gradual, albeit characterized by periods of accelerated reclamation. The legal framework and actual reclamation practice can be traced back to the Roman tradition,m and have been applied to the slowly-evolving landscape ever since. The pushes for transformation can be related to the Crown/State's desire to expand profitable farmland, but provisions to ensure that it remained within the Public Trust prevented the full appropriation of land by private landowners and, consequently, contributed to limit the more recent transformation of lowlands onto residential or industrial uses. In contrast, the San Francisco Bay's estuarine ecosystem went largely undisturbed until the second half of the 19th century. Since then, it experienced the impacts of human activity at an extremely accelerated rate, with the input of sediment from the Central Valley increasing by a full order of magnitude and back within little more than a century. Direct shoreline alteration was equally extensive and, unlike in the Tagus Estuary, the Public Trust over the bed was not fully upheld until the 1960s. Thus, besides transformation into farmland, landfills around the Bay are now abundantly built-over, with uses ranging from salt ponds, industrial zones, and even residential neighborhoods.

While both legal frameworks share a common ancestry which may be traced back to the Roman Law, we have established that they were upheld more rigorously, or at least consistently, in the Tagus Estuary and, as a result, most lowlands around the Estuary remained under public control and free from permanent building. Although most wetlands have been reclaimed, farmland occupies almost all drained areas. Around the SF Bay, estuarine beds and wetlands were, during a period of accelerated urban expansion, sold to private developers and were converted to a much greater extent to industrial, infrastructure, and urban uses. This is in contradiction to the original provisions of the Public Trust Doctrine, and could be characterized as a relaxation of its enforcement during a period when environmental standards were not a priority as compared to the urge to encourage settlement and grow the regional economy.

The standard for the delimitation of the upper limit of the Public Trust/Public Domain is more generous in Portugal than in California. Portugal has, through historic tradition, adopted the Highest Astronomical Tide as a reference, against the Mean High Water standard for California. Portuguese laws also grant the public agencies with a full planning mandate over a 50m strip inland from the HAT line, and an additional 500m buffer with limited planning mandate. In contrast, the BCDC only has a limited planning mandate over a 30m buffer, mostly related to the assurance of public access in new development.

Wetlands around the Tagus Estuary could more easily be allowed to migrate upland as the more sensitive habitat is adjacent to farmland, whereas around the SF Bay most wetlands are severely encroached upon by urban infrastructure. Also, a steady improvement in the Portuguese legal framework, including the expansion of environmental planning mandates of public agencies, now lends the estuary a strong level of protection. On the other hand, SF Bay has experimented with over four decades of wetland restoration and tidal reconnection of formerly diked ponds, and the metropolitan area is now a global leader in green adaptation, with a greater level of involvement of private sector and civil society in climate adaptation efforts.

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3 A TALE OF TWO ESTUARIES: GOVERNANCE, ENVIRONMENTAL PLANNING, AND ADAPTATION TO SEA-LEVEL RISE IN SAN FRANCISCO AND LISBON

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3.1 Introduction

Estuaries are among the most ecologically productive and biodiverse natural environments, hosting wetlands crucial as stops along bird flyways and as nurseries for fish (McLusky 2004, Costa 1999). Estuaries are often good natural harbors, and several of the world's largest port cities developed on estuaries to benefit from both the location at the crossroads between inland and sea trade and the adjacent fertile alluvial floodplains. These cities have encroached upon the estuarine shores degrading the quality of the natural environment, commonly displacing wetland habitat for urban areas and infrastructure (Goals Project 1999, Caçador 2001). Despite recent efforts to protect and restore estuarine ecosystems, both urbanized and still-natural estuarine shorelines are now vulnerable to accelerated sea-level rise by virtue of their extensive areas at or just above mean sea-level (Wong 2014, Ericson 2006, Church 2008, Hanak 2012, Andrade 2002).

In these settings, the cost of inaction in face of rising seas is simply too high (Heberger 2009, EEA 2013, ANPC 2010), motivating some estuarine cities to begin to adapt to sea-level rise. This will require modifications to the urban and environmental planning structure. San Francisco Bay, California, USA, and the Tagus Estuary in the Lisbon Metropolitan Area, Portugal, both large urbanized estuaries, make excellent case studies by virtue of their remarkable geographic similarities but distinct traditions of environmental planning and governance structure.

San Francisco Bay (henceforth, SF Bay), is the estuary of the Sacramento River, and the largest estuary along the west coast of North America. The Tagus Estuary (hereafter, the Tagus Estuary) is the estuary of the Tagus River, and the largest estuary on the Atlantic coast of Europe(Figure 9). The two estuaries are similar in many important respects, but also have notable differences (Table 4). Although SF Bay is significantly larger than the Tagus Estuary in surface area (~1260 km^2 vs ~320 km^2, EPA 2011, Gameiro 2007), both constitute key wetland ecosystems for major flyways and serve as nurseries for important offshore fisheries (Okamoto 2011, Catry 2011, Costa 1999). Today, both SF Bay and the Tagus Estuary are surrounded by large metropolitan areas: the San Francisco Bay Area is home to about 7 million (the second largest metropolitan area on the Pacific coast of North America), and the Lisbon Metropolitan Area has about 3 million and is the largest urban center located directly on the Atlantic Coast of Europe. Geomorphically, both estuaries are "drowned valleys" (McLusky 2004), shaped by alternating episodes of active incision during ice ages and marine transgression during warm periods (Atwater 1977, Vis 2008). These marine and fluvial processes, coupled with active tectonic uplift and subsidence, have created "bottlenecks" at the mouths of both estuaries, partially protecting their wide inner basins and inland deltas.

The Tagus River is dammed by 10 dams on the main river and 80 dams on tributaries (35 in Portugal and 45 in Spain), reflecting the fact that the river passes through many bedrock outcrops that afford good dam sites. The Sacramento River and San Joaquin have fewer dams on the alluvial Central Valley, but virtually all of its tributaries are dammed. Despite this, the Sacramento River system still supports runs of anadromous pacific salmon, which are priority species for conservation efforts. While the Tagus River still hosts several endangered species, communities of anadromous fish have been severely impacted by damming, diversion, overfishing and pollution. Both estuaries experience Mediterranean type climates, with high seasonal and interannual variability in rainfall and thus fresh water inputs into the estuaries. Both estuaries have been subject to deep anthropogenic impacts on their wetland ecosystems and are now under a common threat from sea level rise.

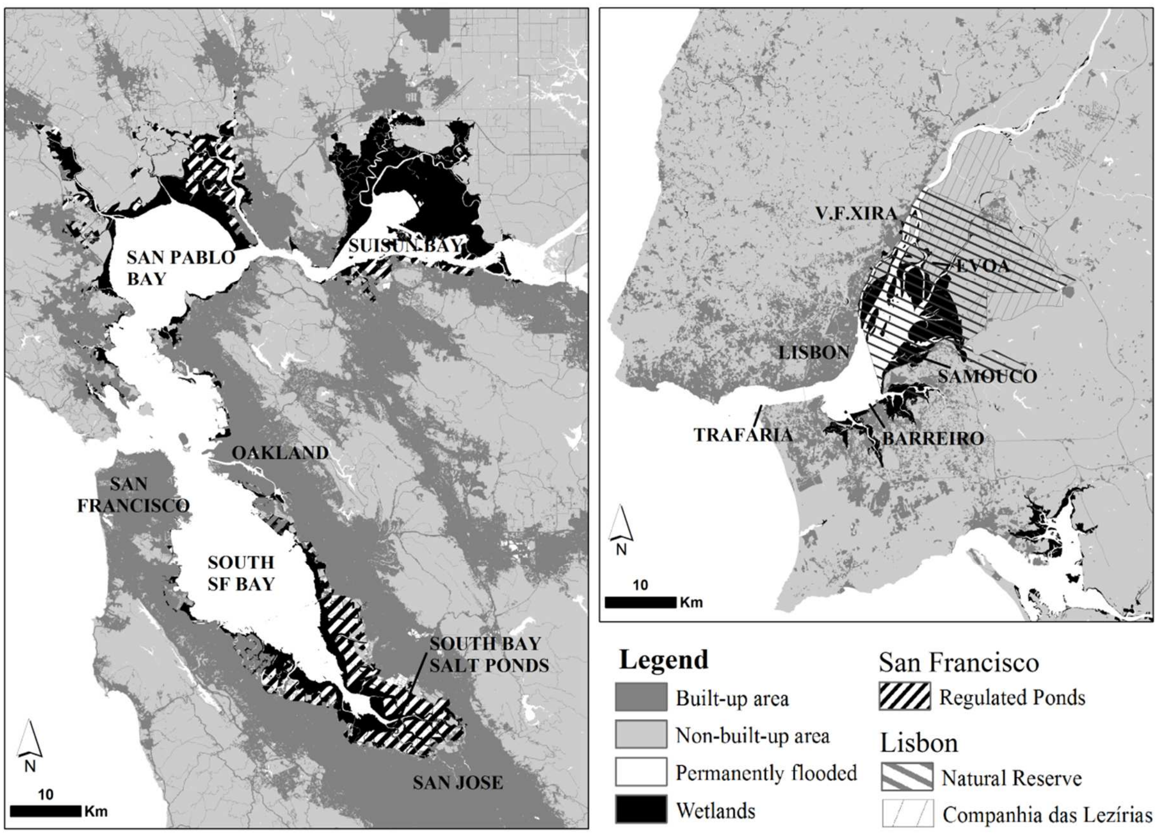

Figure 9 – Maps of the San Francisco (a) and Tagus (b) estuaries shown at the same scale, showing locations referred to in the text.

While physically and ecologically similar, these two estuaries have distinct histories of human occupation and have developed different legal and institutional approaches to land management (Chapter 2), which are reflected both in the nature of the threat now posed by accelerated sea level rise and in the institutional and legal structures in place to protect the remaining wetlands and to respond to sea level rise. Recurrent episodes of flooding in low-lying landfills during storm surges (for instance in Embarcadero, San Francisco, and in Alcântara, Lisbon) reveal that SLR is already producing negative impacts in both estuaries. These extreme events are often triggers for increasing awareness of climate change and its effects (Tollefson 2012), which in turn may lead to expedited incorporation of adaptation onto public policy and legal frameworks (EEA 2012a, IPCC 2012, Birkmann 2010, Carey 2011). Our research compared the governance structure and regulatory/planning frameworks in these two estuaries through review of relevant documents, semi-structured interviews with key players in planning and adaptation to sea-level rise, and examples of concrete instances of sea-level rise adaptation solutions, strategies, and standards being implemented in both regions. Based on this research, we identified opportunities to improve governance frameworks and planning processes.

Metropolitan Areas	**San Francisco Bay Area**	**Lisbon Metropolitan Area**
Population	7,150,739[a]	2,821,876[b]
Total area [Km^2]	17,931	3,002
Pop. Density [people per Km^2]	399	940
Estuaries	**San Francisco Bay**	**Tagus Estuary**
Water surface at high tide [Km^2]	1,260 [c]	320 [d]
Mudflats [Km^2]	118 [e]	152 [f]
Low marsh [Km^2]	19.9 [g]	4.4 [h]
Salt Ponds [Km^2]	239 [i]	<1
Mean tidal range [m]	2.3 [j]	2.4 [d]
Mean tidal prism [m^3]	14.7×10^8 [k]	7.5×10^8 [d]
River basins	**Sacramento - San Joaquin Basin**	**Tagus Basin**
Surface area [Km^2]	153,794	80,629
Average annual unimpaired flow into estuary [hm^3]	34,819 [l]	17,044 [m]
Average annual flow into estuary [hm^3]	~25,000 [n]	~12,500 [l]
Average annual sediment influx into estuary [metric ton/year]	$1\text{-}2 \times 10^6$ [n]	$1\text{-}5 \times 10^6$ [o]

[a] Bay Area Census (MTC-ABAG, 9 Bay Area Counties, 2010 Census); [b] Instituto Nacional de Estatística (2011 Census, NUTS II - Lisbon); [c] EPA 2011; [d] Gameiro 2007; [e] SFEI Baylands *"Bay Flat Total"*; [f] DGT COS 2007 *"Mudflats"*; [g] SFEI Baylands *"Low and Mid Marsh"*; [h] DGT COS 2007 *"Coastal wetlands"*; [i] SFEI Baylands *"Salt Ponds"+"Regulated Ponds"*; [j] Palaima 2012; [k] Gilbert 1917; [l] CDWR 2007: 48; [m] Santos 2002: 144 ; [n] Barnard 2013; [o] Costa 1999

Table 4 – Characteristics of the San Francisco and Tagus estuaries.

These two case-study estuaries can be considered as 'early adopters' of adaptive planning frameworks and solutions within their respective traditions of planning and governance structure (i.e., US and Europe, Svensson 2008) and thus lessons learned from these systems and their comparison may be helpful in the greater context of adaptation across both continents.

3.2 Materials and methods

3.2.1 Reconstruction of Environmental Histories and vulnerability to sea-level rise

For San Francisco Bay, we used as reference prior reconstructions of past geography and bathymetry (Schoellhamer 2013, Kirwan 2011, Goals Project 1999, Watson 2013, Atwater 1977, Wright 2004, Okamoto 2011). To reconstruct the evolution of the Tagus estuary, we drew upon prior studies of historical change and paleostratigraphy (Vis 2008, Martins 2010, Dias 1997, Uribelarrea 2003), and primary sources, for historical documentation of land-use (Beirante 1998, Madaleno 2006, Soares 2011) and for the characterization and modern distribution of wetlands (Vale 1987, Gameiro 2007, Ribeiro 2003, Martins 2010).

To compare the vulnerability of estuarine shoreline lands to sea level rise, we superimposed projected future sea levels on digital terrain models (DTMs) of the two estuaries. We very coarsely simulated the effects of different thresholds of SLR over the low-lying areas of both estuaries, while simplifying maps to portray only three main land-cover categories: urban areas, rural areas, and wetlands. In this simple analysis, we determined extent of inundation from future static sea level rise (i.e., not accounting for wave run-up or local hydraulic effects) by superimposing elevated sea levels over current land use and wetland distribution (Table 5). For each elevation, we determined the potential exposure to future flooding of each major land use.

Layers	**San Francisco Bay Area**	**Lisbon Metropolitan Area**	***Data processing***
Altimetry	National Elevation Dataset - USGS	Shuttle Radar Topographic Mission - NASA	Creation of *mask* layers for current MSL, +1m, +2m, +3m, +5m and +10m
Land Use	National Land Cover Database 2006 - USGS	Carta de Ocupação de Solo 2007 - IGP	Reclassification of land use into three classes: built-up areas, non-built-up areas, permanently flooded areas
Wetland maps	EcoAtlas Modern Baylands - SFEI	Georreferrenced from Ribeiro 2003, Gameiro 2007	Reclassification of wetlands into three categories: mudflat, saltmarsh, and regulated/salt ponds

Table 5 – Data sources used in the flood mapping of both estuaries.

Similar analyses have been previously undertaken specifically for the SF Bay and California (BCDC 2011a, Heberger 2009, OCOF 2013), or more broadly, for all US coastal areas (NOAA 2011, Climate Central 2014). For the Tagus Estuary, the main SLR modelling effort has been carried out by Project Morpheed (Freire 2013) of the Portuguese National Laboratory of Civil Engineering (LNEC). These simulations were used as a reference for the Tagus Estuary Management Plan (APA 2013). Other simulations have focused especially on local impacts over urbanized waterfronts, such as the project "Estuários e Deltas Urbanizados" (Costa 2013) and "CHANGE - Mudanças Climáticas, Costeiras e Sociais" (Schmidt 2013).

However, to ensure the consistency in same methods and assumptions in the comparative analyses of both estuaries (i.e., to avoid apparent differences that might be artifacts of the methods rather than real differences between the two cases), we independently conducted these analyses. Thus, our results might differ in some details from prior studies, but our emphasis was on understanding large-scale trends and differences between the two estuaries, and thus replicating the analysis in a consistent manner for both estuaries was necessary.

The resulting flood maps and tables are presented in Appendices A, B, and C.

3.2.2 Documentation and Analysis of Key Players and Plan Development

We conducted an in-depth analysis of the planning processes leading to the publication of the Climate Change Bay Plan Amendment (BCDC 2011b) and near-publication of the Tagus Estuary Management Plan (APA 2013).

We conducted semi-structured interviews with 12 policy makers, experts and stakeholders in both cities. Neuman (1991) describes different types of interview. Structured interviews typically aim at obtaining 'processable' data. As such, typified answers, that could be easily coded and compared as 'data' are preferred to open-ended entries. Given the type of information required in the study of urbanized estuaries, semi-structured interviews are more suited. The objective of the interviews is to obtain as much relevant information as possible from an expert or to accurately portrait the position and opinions of a stakeholder with regards to a given problem. Similar methods have been employed in several environmental governance and climate change-related studies, including Swanson (1975), O'Toole (2013) and Schmidt (2013).

We guided each interview around a loose script with 5 pre-set topics:

> 1 – How do you/your institution perceive sea-level rise: as a threat, an opportunity, or both?
>
> 2 – What is you institution's main role and stake regarding SLR: Environmental protection; Defense of its jurisdiction; Protection of investments/ infrastructure; Other – which?
>
> 3 – Which would be the main drivers/goals of present or future adaptation strategies?
>
> 4 – How do you foresee SLR affecting the role and/or procedures of your institution within the next 10, 25 or 50 years?
>
> 5 – Did your institution revise its standards & practices to accommodate adaptation to SLR? Could you specify a few relevant measures?

Interviews lasted about 2 hours, and interviewees were allowed to pursue other topics related to regional planning and SLR adaptation. We conducted 12 interviews (6 in each city) with a total of 16 participating stakeholders and experts.

Based on the review of planning documents from 1965 to present and our interviews with policy makers and stakeholders, we identified all the agencies involved in decision making and/or plan implementation in both estuaries. We also identified the number of ecological reserves and open spaces in each estuary system, as an indication of complexity in management of estuarine lands and water. For a recent wetlands restoration initiative in each estuary (the South Bay Salt Ponds Restoration Project in SF Bay, and the Samouco Salt Ponds Restoration Project in the Tagus Estuary), we identified key players and their roles.

3.3 Results

3.3.1 Environmental histories and resulting land-use patterns of the estuaries

San Francisco Bay

What is now San Francisco Bay was a broad alluvial valley during low stands of sea level during the glacial advances of the Pleistocene. After the last ice age, sea level rose sharply 60m between 11,650–7000 Y.B.P., flooding the SF Bay (Smith 2011, Atwater 1977). Since then, the SF Bay has been filling with sediments from its tributary rivers and through expansion of tidal wetlands. Wetland expansion accelerated during the Little Ice Age (ca. 1550 to ca. 1850), such that the 19^{th}-century extent of tidal wetlands (commonly used as a reference for tidal wetland restoration) may have been unusually large (Watson 2013).

The SF Bay Area remained a largely undisturbed natural environment up until the mid-1800s, but the influx of European settlers during the gold rush caused massive alterations over a short timeframe. Alterations to the land cover of the river basin and, especially, the use of hydraulic mining technology in the gold fields in the second half of the 19^{th} century produced a 10-fold increase to the input of sediment to the SF Bay. However, by the mid-20^{th} century, sediment delivery had declined sharply as a result of sediment trapping by dams (Orr 2003, Wright 2004), and has likely fallen below pre-disturbance levels, as the remnant sediment from the hydraulic mining era leaves the system and remobilization of additional sediment from the interior valleys becomes less likely under the current management of reservoir capacity. The lack of sediment supply in reaches downstream of dams ("sediment starvation", Kondolf 1997) now poses a limitation on efforts to rebuild tidal wetlands in SF Bay (Barnard 2013, Schoellhamer 2013, Wright 2004, Watson 2013).

Until 1965, the SF Bay shorelines did not enjoy legal protection, and they were extensively altered by dyking and landfilling, activities encouraged by national and state law. At the federal level, the Arkansas Act (1850) made appropriations of "swamp and overflowed" lands a prerogative of the states, and California passed legislation promoting the dredging and filling of wetlands for agriculture (Luken 1974, Swanson 1975). Various estimates of loss of the original wetlands to landfilling and dyking indicate that over 90 percent of the mid-19^{th}-century extent of tidal wetlands was lost by the late 20^{th} century (Goals Project 1999, Williams 2001, Madsen 2007).

The tipping point that put a halt to the reclamation frenzy came after two infamous projects, the Reber Plan of the 1940s (Price 2002) and the United States Army Corps of Engineers (USACE) study that followed (Swanson 1975, BCDC 1998:4). This was a proposal to landfill most shallow areas of SF Bay and to create two large earthen dams to transform San Pablo, Suisun and South SF Bay into fresh water reservoirs. These proposals were met with public outrage and were eventually dismissed by USACE as inviable due to their environmental impacts (Saunders 2009). However, the struggle to protect SF Bay against extensive fill had a deep impact on public perception of the SF Bay, and motivated the emergence of environmental NGOs, passage of legislation establishing public agencies, and public-private partnerships dealing specifically with environmental issues related to the SF Bay (Walker 2009). In particular, the NGO Save the Bay successfully lobbied for the MacAteer-Petris Act (described below), which halted fill of the open Bay waters and within a 30-m coastal strip in 1965.

The SF Bay was polluted by discharge of untreated industrial and municipal sewage until the closure of many bayside industries and extensive construction of wastewater treatment plants following passage of the Clean Water Act (Okamoto 2011).

Nonetheless, by 1965, extensive areas of tidal and sub-tidal lands had been dyked off and/or filled, and converted to residential and industrial uses. Much of the land originally "reclaimed" for agriculture, and part of that dyked-off as salt ponds, was later converted to infrastructure, industrial, and urban uses. Salt ponds at one time occupied as much as 36,000 ha (Goals Project 1999), part of which have since been converted to other uses or restored to managed wetlands, and we estimate that close to 20,000 ha of former Baylands (~8.6% of the maximum historical extent of the SF Bay) have been permanently converted to urban areas and infrastructure (Chapter 2). Areas more than 30 meters from the 1965 shoreline and already zoned for commercial, industrial, or residential uses could still be built upon. The result was extensive development of buildings and infrastructure within a few meters above mean sea level along the margins of SF Bay.

The Tagus Estuary

The Tagus Estuary was similarly created after the end of the last glacial period by flooding during the sharp increase in global sea-level (Dias 1997, Vis 2008). Although accurate descriptions of the estuary are lacking before formation of the Kingdom of Portugal (mid-12th century), some documents hint that there was already a practice of draining the *lezírias* (tidal flats) for farmlands before then (Beirante 1998). The modification of the watershed (Uribelarrea 2003) and virtual extirpation of primeval forests was completed before the end of the middle ages (Pinto 2012), resulting in greater influx of sediments onto the estuary, which likely accelerated the rate of wetland expansion and extent of potential *lezírias* farmland. Since the mid-20th century, dams on the mainstem Tagus and its tributaries (in both Spain and Portugal) have extirpated anadromous fish runs and reduced the sediment yields dramatically (Andrade 2002: 187).

Attempts to defend the highly productive agricultural lands on Tagus delta (the upper part of the estuary) against floods and high tides required constant maintenance of protective walls. Several campaigns to encourage further creation of these farmlands are documented in the historical record (Madaleno 2006, Beirante 1998, Martins 2010). These suggest that either these farmlands were cyclically abandoned and the crown had to promote their reconstruction, and/or that the expansion of the *lezírias* farmlands advanced with the natural process of delta progradation. This historical practice is consistent with the practice of reserving all land below "the December High Waters" for the Crown (that is, in Public Domain), a measure grounded on the old Roman tradition of a public trust protecting all navigable waters and floodplains (Beirante 1998). In 1864, all shores subject to inundation at the Highest Astronomical Tide (HAT), plus a 50-m wide strip inland, were designated Public Domain by the Royal Decree of December 31st. Some 30 years before, the *Companhia das Lezírias*, then a private society, was created to manage the farmlands belonging to the Crown Prince. The model of public-led management of the bulk of farmland located on the alluvial plain persists to this day, and has largely prevented urbanisation of these productive agricultural lands. The last major effort to reclaim tidal lands (probably a combination of salt flats and relic high marsh) for agriculture was the 1910 campaign to drain 4,000 ha in the Lezíria Grande (Madaleno 2006). In the mid 20th century some areas in the south bank of the estuary were landfilled for the expansion of large industrial units and to expand the waterfront available for shipping, but these areas combined were restricted to less than 700 ha (Chapter 2) or less than 1% of the maximum extent of estuarine lands. A plan that proposed the reclamation of a further 8,000 ha of shallow estuarine areas, including mudflats and most of the remaining patches of salt marsh, was considered in the 1950s, but the project was postponed and definitively abandoned for environmental reasons in the 1970s (Costa 1999: 41).

The estuary's water quality was compromised by untreated industrial and sewage effluent, with severe impacts on the estuarine ecosystem (Costa 1999, Caçador 2001). Tightened water quality standards, closing down of major industries, and major investments in primary and secondary water treatment along the Tagus river basin at the turn of the 21st century (Costa 1999: 164, Soares 2011) resulted in steady improvements in the water quality in recent decades.

Since the late 1980s, the original Public Domain has been reinforced with a limited planning mandate over a transitional zone, a buffer extending 500 m inland from the HAT + 50 m. This, in addition to legislation protecting specifically wetlands, the best soils, the best habitat and sensitive areas, means both wetlands and upland farmland and forest patches around the estuary are well protected from transformation. Furthermore, the national law establishes that "land lost to the sea" through erosion is to be automatically incorporated into the Public Domain, and the adjoining buffers realigned according to the new shoreline. If this jurisprudence is upheld, it establishes a very strong public trust doctrine regarding rising seas. Equally, public environmental protection and port agencies have been granted very strong mandates, which have steadily been expanded through the passing of new legislation, often championed by the European Commission and reflecting advancing paradigms in environmental protection and resource management.

The result is that, while there are extensive urban waterfronts around the Tagus Estuary, the vast majority of low-lying areas along the estuary shoreline are, to this day, occupied almost exclusively by wetlands and agricultural land (in strong contrast to SF Bay).

3.3.2 The Planning Instruments and Planning Processes

San Francisco Bay

The institutional framework of San Francisco Bay is exceptionally complex, with over 100 local governments and multiple layers of state, regional, and federal authorities (Figure 10). This reflects a Californian preference for the multiplication of public agencies pursuing very specific and narrow mandates (Fulton 2012: 76, 89-104). The planning process is also characterized by a great level of involvement in the decision-making process of a multitude of NGOs, private interest groups, or even individual citizens (Fulton 2012: 108-109).

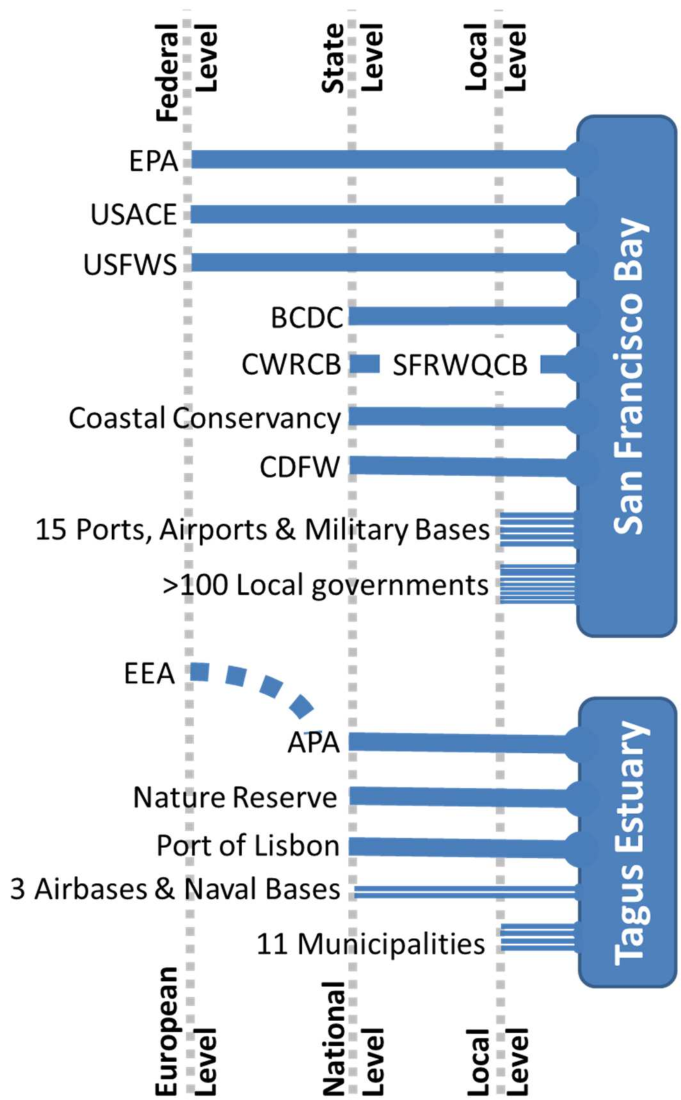

Figure 10 – Complexity of the planning systems.

The main entity responsible for the coordination of environmental protection in the SF Bay Region is the San Francisco Bay Conservation and Development Commission (BCDC), created by the McAteer-Petris Act, passed by the California Legislature in 1965. The Act specifically addressed the relentless landfilling around the SF Bay and reflected the increasing awareness and concern over the extirpation of its wetland ecosystems, raised by the emergence of a second-wave of local environmental activism, championed by the NGO Save The Bay (Walker 2009). At the time of its creation, the BCDC was the first coastal commission established in the United States. It predates several landmark state and federal legal documents addressing environmental protection, such as the State's Porter-Cologne Water Quality Control Act of 1969 and the Federal Coastal Zone Management Act and the Clean Water Act, both from 1972. It equally influenced the establishment of the State-wide California Coastal Commission (1972) and several other similar agencies across the country.

As a trailblazer, BCDC's original mandate was somewhat narrow (Davoren 1982), and its authorities were overlain on top of the authorities of pre-existing agencies, within a very complex governance structure composed of three levels of government: federal, state, and local. The California Water Resources Control Board (CWRCB) and the SF Regional Water Quality Control Board (SFRWQCB) are both derived from a State agency dating back to 1949 tasked with the difficult balancing of water allocations across the state, and since 1972, with enforcing aspects of the federal Clean Water Act. Through basin-wide as well as local actions, these regional boards have been successful in vastly improving the water quality of the SF Bay.

The US Army Corps of Engineers remains largely responsible for the management of dredging, now mostly associated with the maintenance of navigation channels on the SF Bay (LMTS 2001). Both the US Environmental Protection Agency (EPA, created in 1970) and the Corps are tasked with issuing and enforcing permits for dredging and filling, including on wetlands and salt ponds under the Clean Water Act. The BCDC's mission has been complemented by the California Coastal Conservancy (1976), dedicated more specifically to the protection and restoration of coastal and wetland habitat.

Several other agencies and a myriad of city governments and special districts (local entities typically created to pursue a single function, such as water treatment, education or flood control) also have stakes on shoreline development, coastal defense infrastructure, and environmental protection. Given the complexity of this institutional framework, it is no wonder that, ever since its creation, the BCDC had to set up collaborative mechanisms to engage local, state, and federal agencies in establishing planning and protection strategies and coordinating actions and standards (Davoren 1982, Eichenberg 2013).

The Bay Plan Climate Change Amendment

The main document organizing environmental protection of SF Bay is known as the "Bay Plan". First published in 1968 by the BCDC, it established the "blueprint" for the protection of the SF Bay (Schoop 1971). The Plan has been amended several times since its creation. Our focus is mainly on the most recent Climate Change Amendment (BCDC 2011b), intended to reflect current knowledge of sea level rise and its implications for SF Bay.

From the onset, the McAteer-Petris Act sought to put a halt to the landfilling of the SF Bay. The Plan therefore strictly regulates all filling within 100ft inland (~30m) from the Mean High Tide line. It established a zero-net-loss policy on Baylands, which promotes the offset of all landfill and dredging through onsite remediation or off-site compensation of the lost tidal lands. This practice has been responsible for a few of the early wetland restoration efforts, which have expanded to become one of the staples of Bay Area environmental protection (interviews 5, 8, 10 & 11). The Plan also addresses and articulates interventions requiring landfilling or dredging, such as the deepening of navigation channels or the expansion and maintenance of port and airport infrastructure.

Nevertheless, the Amendment was limited in its scope by the equally narrow planning mandate within which the BCDC has to operate: decisive action in preventing new development just above the current public trust is severely restricted, and mostly limited to the enforcement of "maximum feasible public access" and the recommendation to discourage low-land development. All further proposals that could legally deter it, though, were met with strong resistance by the business community and some local governments, and even BCDC's flood maps for 16" and 55" of SLR, designed as a tool to raise awareness to the foreseeable consequences of climate change, had to be annexed to the Plan as a non-binding element with no legal standing (Eichenberg 2013). Its shortcomings, especially when it comes to the inclusion of binding measures related to shoreline land use, is equally revealing of some issues influencing the environmental planning of the SF Bay, as we shall discuss further ahead.

The Tagus Estuary

The Tagus Estuary's governance structure is comparatively much simpler, with fewer public agencies involved and more limited input from stakeholders (Figure 10). Environmental planning initiatives and revisions to regulation are characterized by relatively simple direct negotiations between public agencies, a top-down decision-making structure, and strong (and frequently expanded) mandates supported by the legislature. Expanded environmental protection standards for water quality, land-use planning, and environmental protection have typically been reflected in expanded mandates and jurisdictions of already-existing national agencies.

The institutional framework is also much simplified because the roles of different levels of government are more clearly defined. The equivalent of the US Federal level would be the European Parliament, Commision, and executive agencies such as the European Environment Agency (EEA), but EU directives and standards must first be transposed into national legislation before influencing national and local government actions (Pettersson 2013).

Because Portugal lacks regional governments (Thiel 2015), this effectively means all nation-wide and regional coordination is nested under national agencies. These large agencies and institutes, such as the Portuguese Environment Agency (APA), are typically organized through a branching structure of departments and regional offices, similar to that of US federal agencies. Local governments are limited to one form, that of the municipalities (which typically include both urban centers and surrounding rural areas) and there is no concept of incorporated city vs. county as in the US. In terms of their attributions, Portuguese municipalities are comparable to US situations where city and county boundaries coincide (such as the City and County of San Francisco). They have a strong planning autonomy for land-use choices, especially regarding urban planning, but are required to reflect all public easements and environmental standards, emanating from upper-level plans and revised laws, in their municipal land-use plans.

The APA oversees environmental planning efforts, and has to coordinate with the Tagus Estuary Nature Reserve, a national-level park, which grants special protection and enhanced monitoring of environmental performance and human activities over the most sensitive wetland and adjacent areas. Established in 1976, the Reserve is managed by the Institute for Nature Conservation and Biodiversity. The Port Authority, established as autonomous public administration in 1907, has a jurisdiction over most shorelines around the Estuary, but upholds it only over "active" port areas, mostly concentrated in urban waterfronts in the municipalities of Lisbon, Almada, Barreiro and Vila Franca de Xira. It answers directly to the Ministry of Economy, and coordinates most dredging operations in the Estuary, in coordination with the APA. Since 2009, some stretches of urban riverfront with no port use have been transferred from the jurisdiction of the Port Authority to the municipalities.

The Tagus Estuary Management Plan

The estuary's major environmental protection instrument will be the new Estuary Management Plan (Estuary Plan, APA 2013). It is instructive to go briefly through the process by which the Estuary Plan was developed. The European Union Water Framework Directive (WFD, Directive 2000/60/EC, adopted in 2000) requires river-basin level planning and management of water. In Portugal, and after the transposition of the WFD onto the National Water Law (Law 58/2005), five Hydrographic Region Administrations (in Portuguese, Administrações de Região Hidrográfica, or ARH), branching out of the Portuguese Water Institute, were established as the 'competent authorities' to carry out the actions required by the WFD. These included the creation of River Basin Plans, Coastal Management Plans, Reservoir Management Plans, and Estuary Management Plans.

However, in 2012, the ARHs were eliminated as part of austerity measures, and the mandates and capabilities of the ARHs were collapsed into an autonomous unit within the APA. For the Tagus Estuary, environmental planning efforts are currently led by the APA. Besides inheriting all the capabilities and mandates of the Tagus ARH, the APA also includes departments tasked with national and regional climate adaptation strategies, the coordination and funding of environmental mitigation, coastal defense infrastructure, water quality, and flood management, and is responsible for environmental licensing of water uses, dredging and filling operations. It oversees the protection of the Public Domain and all wetlands.

The Estuary Plan will be one of the last elements required by the Portuguese legislation transposed from the WFD to materialize. In pursuance of the National

Water Law (Law 58/2005), the Decree-of-Law 129/2008 sets the specific legal framework for the Estuarine Management Plans. This planning instrument will coordinate the activities of public agencies and private landowners and activities. It also articulates the existing protection mechanisms and expands wetland monitoring (already routinely conducted by the Nature Reserve) to other patches of salt marsh, beaches and mudflat, notably along south-bank embayments. It establishes priority interventions in the remediation of several natural or semi-natural shorelines.

Having been elaborated in close coordination with the Nature Reserve and the Port Authority, the Plan also received inputs from the Nature Reserve's own management plan (which led to the inclusion of that instrument's best practices and knowledge on wetland protection and monitoring) and informed the revision of the Port Authority's Dredging Plan, which allowed best environmental practices to be defined with regard to timing, extent, and location of dredging and deposition of dredged material in the estuary. It included the provision to deposit clean dredge material in upstream locations, from whence it can be recirculated through the estuary as suspended sediment, to support wetland accretion through sediment fixation.

Under the then-autonomous Tagus ARH, more direct and fruitful cooperation occurred between institutions during the plan's elaboration, as was acknowledged by Interviewees 1, 3 and 12, but public participation in the decision-making process remained limited, especially when compared to the levels of stakeholder involvement in SF Bay. Nevertheless, the ARH established good communication channels with other public agencies and held public meetings to inform and engage local populations and stakeholders.

Further involvement may require a longer tradition of collaboration in planning, although the Plan marks somewhat of a departure from the typical Portuguese coastal planning process, as described by Schmidt (2013), especially in that there was improved communication among major stakeholders, a clarification of each agency's role, and a greater involvement of the scientific community (Interviews 1 and 12). Nevertheless, participation in the definition of regional strategies and most regulations included in the Estuary Plan was concentrated among a few large public agencies (mostly the ARH and the Port of Lisbon, with additional inputs from the Natural Reserve and consultation of experts and municipalities) and reflected simple negotiations through direct channels of communication.

Engagement of the general public and other stakeholders was mostly restricted to formal mechanisms such as notices or invitations for public consultation of plans, which may be attributed to a two-way distrust: the general public is often perceived by planning agents as being unable to contribute constructively to the process beyond the assurance of personal stakes, and the latter are viewed as unable or unwilling to engage in truly participatory processes, and participation is sometimes discredited as an inconsequential process (Schmidt 2014). The ARH nevertheless attempted to create more frequent platforms for public engagement, including local forums where inputs from residents and local interest groups were received.

As the need for environmental protection becomes an uncontroversial staple, grounded on established legal standards, these agencies' positions on environmental planning often coincide (or, at least, do not clash), and more open collaboration among them has improved articulation of policies and interventions (Interviews 3, 4, 12).

However, the relative lack of public involvement in plan formulation and decision-making means that top-down decisions reached through compromise among national agencies can trigger strong controversy when presented to the public and local governments as fait accompli. These are often smaller decisions imposed onto a greater planning framework, but yet, through the controversy they generate, may impair the approval of the otherwise well-received broader document.

This occurred with the Estuary Plan when its preliminary version was released to stakeholders in 2012: In addition to the consensual coordination of environmental planning across the Estuary, the Plan included a land reserve for the future construction of the new container port terminal, then proposed for Trafaria. The inclusion of such a large infrastructure project in the plan, without prior public consultation over potential environmental, economic, and social impacts, was met with intense resistance by environmental NGOs and citizen groups.

The situation has been further complicated by institutional changes, as the five ARH have been merged into an expanded Portuguese Environmental Agency. Although most of the former agencies' structures remained intact, the simple integration within a much larger and complex hierarchy has impaired their ability to successfully conclude their planning efforts, by: (1) leading to a much limited ability to independently establish direct communication channels with other agencies and local actors (as mentioned in Interview 12); and, (2) creating a less direct communication route to the upper levels of central government and legislators, which now has to be navigated along competing demands from several other regional plans and interests.

Likely as a consequence of this less streamlined decision-making structure and the controversy related to the new container terminal, the Estuary Plan has been in "limbo" for over two years. The Plan awaits only a final conciliation stage and ratification, but this has proved elusive because of the resistance to the new container port terminal, which was effectively "slipped into" the Plan without public consultation or buy-in.

3.3.3 Comparing Conservation and Sea-Level-Rise Adaptation Efforts

Conservation efforts

The management of the shorelines of SF Bay is a complex business. Besides the extensive sections of shoreline that have been landfilled and modified into infrastructure such as ports, airports and transportation corridors, the natural and semi-natural shorelines are currently dispersed over 70 nature reserves of all sizes, from the large national wildlife refuges to small wetland patches and several public open spaces located directly along the shore. These parks and reserves are managed by at least 30 different entities, of which 3 are federal agencies, 3 state agencies, 21 local governments, and 3 NGOs. In contrast, all natural shorelines of the Tagus Estuary are managed under two public agencies: the Tagus Estuary Nature Reserve (protecting the more sensitive wetland habitat along the upper section of the estuary), and Portuguese Environmental Agency (APA, which manages all other natural shorelines). The exceptions are two large waterfront parks and a newly created local reserve that are directly managed by municipalities (Figure 11).

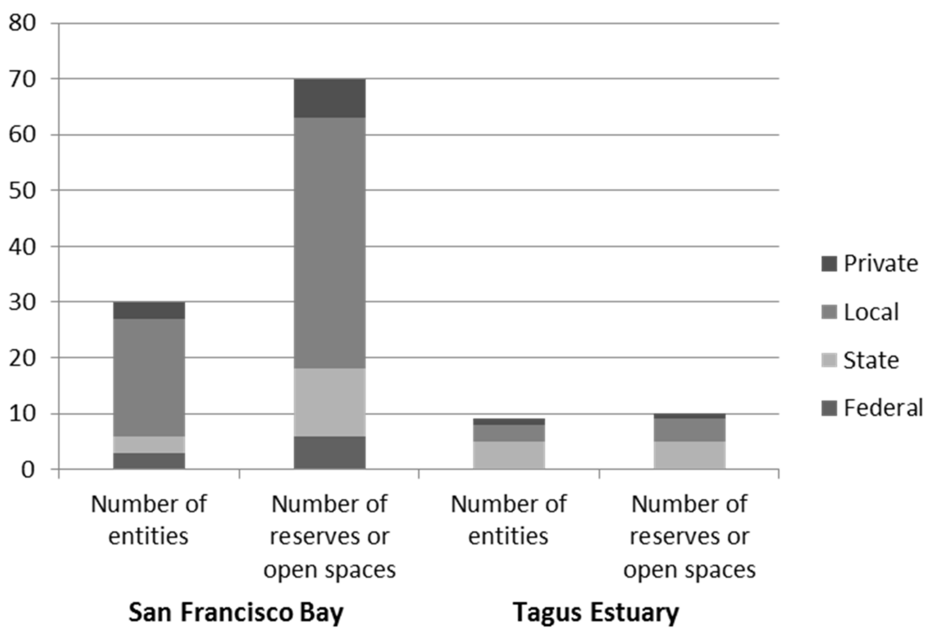

Figure 11 – Entities involved in the management of Bay shorelines (Nature reserves and public open spaces).

Equally, the instruments for protection of wetlands are diverse. Around the SF Bay region, where the legal mechanisms available for controlling development outside floodplains and existing wetlands are limited, the focus is on the rehabilitation of as much of the remaining wetlands and salt ponds as possible. Most major restoration efforts have focused on the conversion of salt ponds, which at one time took over as much as 21,000 ha (Luken 1974) of former wetlands, especially on the South Bay. The fact that these salt ponds have remained important bird habitats and fall within the direct jurisdiction of the BCDC makes them especially appropriate for systematic restoration.

The South Bay Salt Ponds Restoration Project (SBSPRP 2014) is especially significant, constituting one of the largest wetlands restoration projects in North America. Resulting from a large bulk purchase of ponds from Cargill Salt, the land was purchased for $100 Million plus $143 Million in federal tax write-offs (Fischer 2007), with funds from the State (California Department of Fish & Wildlife), Federal (US Fish & Wildlife Service) and private patronage from 4 donors. The ongoing restoration efforts are coordinated by the Coastal Conservancy through a partnership including about 50 different entities, ranging from federal and state agencies to local city governments, special districts and private partners. The magnitude of the project should be better understood if we take into consideration that the area of wetland that will be restored through this project (~6,000 ha, including both former ponds reconnected to tidal action and managed ponds) is more than the cumulative area (~4400 ha) of all restoration efforts completed up to 2008 (Kondolf 2008, Interview 11).

In Lisbon, most conservation efforts have been linked, directly or indirectly, to the preservation of the public domain (deriving from the old tradition of public trust over navigable waters). The original standard of protection up to the highest astronomical tide (HAT) was expanded with a buffer extending another 50m inland with a public planning mandate and severe restrictions on new construction and modification of land cover. All wetlands are thus included in the definition, although public-driven irrigation projects, the expansion of port infrastructure, and a few industrial developments were given the go-ahead up to the mid-20th century.

Since the 70s, new legislation started specifically addressing the protection of wetlands, rather than simply lands under tidal influence, and this was reinforced with the creation of the Tagus Nature Reserve in 1976, protecting the most sensitive habitats and creating habitat management plans for adjacent lands. Further expansion of the Public Domain regime created the concept of adjacent lands, which grant limited planning mandates to public agencies. In the specific case of the Tagus Estuary Management Plan, this buffer was set at 500m inland from the HAT line+50m.

The fact that most alluvial farmland has belonged to the State for most of its existence and managed by a single entity, has promoted their sustainable management (Madaleno 2006, Interview 4), such that these lands now also provide valuable habitat and foraging grounds for several migrating bird species. The attitude towards environmental protection is therefore mostly one, literally, of conservation. Small restoration initiatives have been promoted, the largest one resulting from environmental remediation from the building of the Vasco da Gama Bridge. The Samouco Salt Ponds, which were already frequented by several species, were restored and are currently managed so as to provide maximum benefit for shorebirds. The recently created EVOA (Espaço de Visitação e Observação de Aves) is an artificial wetland with a system of ponds targeted at several sensitive and iconic species and, less than three years after being created, is already common roosting habitat for several species (Interview 9).

In Figure 12, we compare the restoration projects for the Samouco salt ponds and the South Bay Salt Ponds Restoration Project. While evidently having greatly different scopes and dimensions, it is worthy to notice that the costs of intervention – and, especially, the estimated cost per unit of area – are disproportionately greater for the SF Bay Area intervention. While the complexity of the intervention may partially explain the difference, other factors may weigh in, such as the cost of land acquisition (as is the common practice for environmental protection efforts in the US), the cost of infrastructure and coastal defense retrofitting (inevitable given that most ponds are directly adjacent to urban areas protected by levees) and even an exponentially greater cost with permitting and documentation (even in when only public entities are involved) (Interview 11).

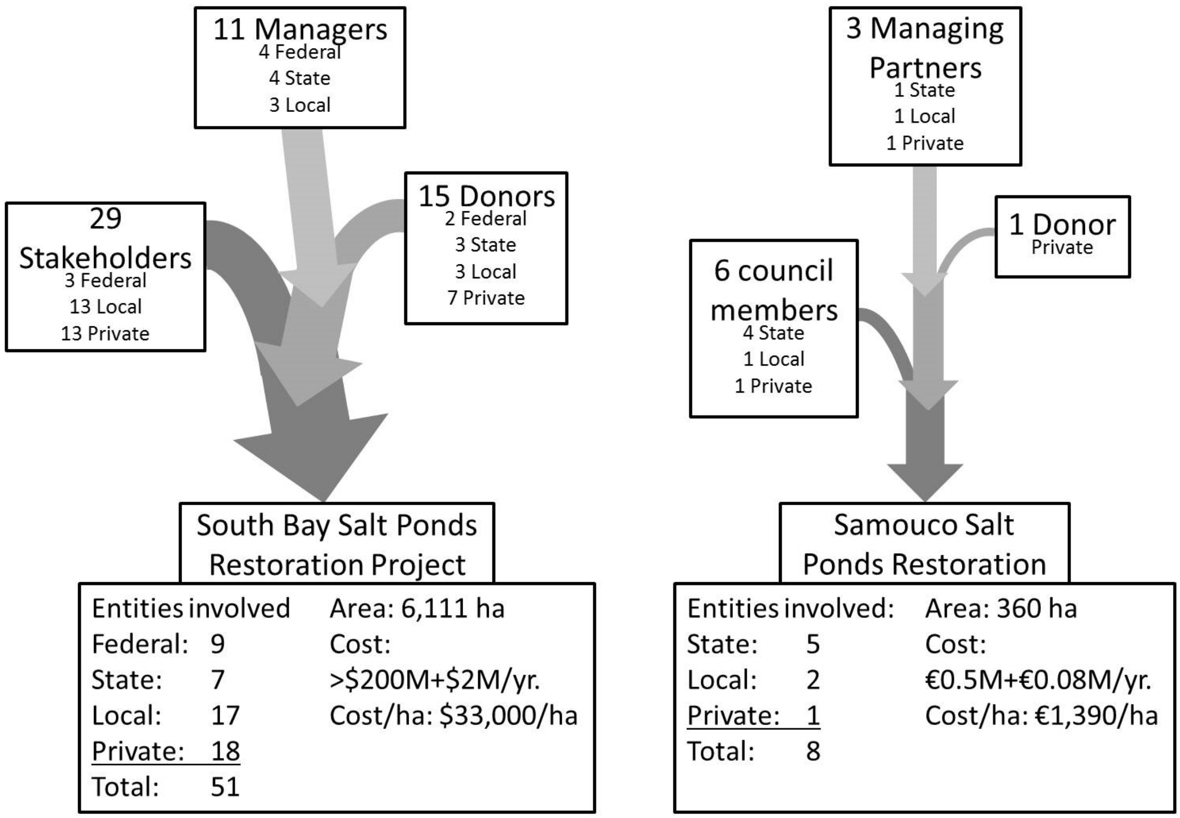

Figure 12 – Entities and numbers involved in the South Bay Salt Ponds and the Samouco Salt Ponds Restoration Projects.

SLR adaptation

Appendices A, B, and C contain the flood maps and resulting tables, which served as the basis of the following analysis.

The San Francisco Bay and the Tagus Estuary will likely be impacted differently by SLR. This is due to the fact that most of the effects felt on these urbanized shorelines are not directly the result of SLR itself, but rather a consequence of the level of exposure to SLR.

Around SF Bay, extensive development over landfill occurred, especially during the first six decades of the 20th century. As such, a lot of highly vulnerable, and valuable, real-estate development and infrastructure is located within a couple of meters of current mean sea-level. In Lisbon, most development took place at higher elevations, and most very low-lying land is occupied by farmland. In Figure 13, it is apparent that at 1-m above present mean sea level (MSL) (roughly equivalent to today's mean high tide), mostly wetlands would be affected in both estuaries, but at only 2 m above current MSL (at the high-end of estimates being advanced for the next 100-yrs), considerable areas of urbanized lowland around the SF Bay would already be rendered below MSL.

This rise of 2m in sea level may take two to three centuries, but could be reached much earlier if Greenland and Antarctic ice sheet meltdown is accelerated (Church 2008, Wong 2014). For this level of SLR, about 10,000 ha of non-artificial (not built, e.g., agricultural, forest, open-space) land, and about 10,000 ha of artificial (developed) would be inundated. About 60,000 ha of wetlands would likely be lost unless given the opportunity to migrate, as the higher rates of SLR would likely be incompatible with simple accretion (Titus 1990, Orr 2003, Stralberg 2011, Swanson 2013). Around the SF Bay, further SLR would disproportionately affect artificial (developed) lands: over 28,000 ha of urban areas are less than 5m above present MSL (~23,5% of all land affected) and as much as 55,000 ha less than 10m above present MSL (~35,5% of total).

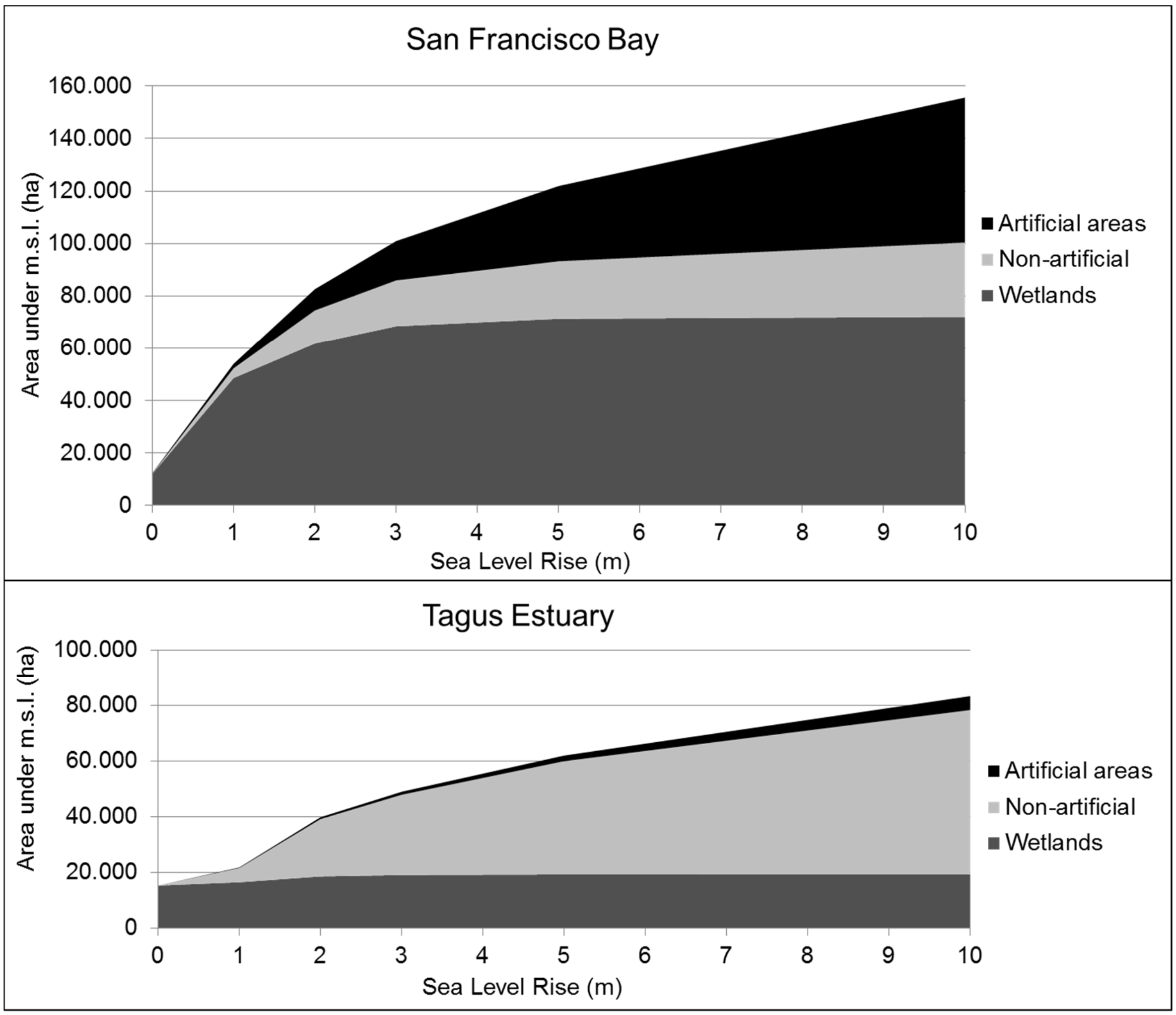

Figure 13 – Cumulative area of Wetlands, non-artificial, and artificial areas rendered below mean sea level with sea level rise, in San Francisco Bay and the Tagus Estuary.

By contrast, the Tagus Estuary is flanked mostly by wetlands and rural areas. These are areas across which rising seas (and, for that matter, migrating wetlands) can transgress with little impact to human settlement. A 2-m rise in sea level would submerge 25,000 ha of non-developed land (mostly agriculture), about 15,000 ha of wetlands (which may be able to accrete or migrate, Titus 1990), and less than 1,000 ha of artificial (built) land. This pattern would persist for higher SLR elevations, as only about 2,000 ha of urban areas are located less than 5m above present MSL (~3.2% of all land rendered below that elevated sea-level) and 5,000 ha below 10m (~6% of total).

It should be mentioned that even this lower stage (+2m SLR) is significantly higher than a present day's King Tide for the SF Bay and, under that scenario, exceptional high tides may be as high as 3-4m above current MSL. Past emissions have already triggered processes which may be conducive of further increases in eustatic sea levels of up to 7m above current MSL (IPCC 2014: 191). Although such SLR is not to be expected for several centuries, it is worth noting that our simple analysis understates the actual impact of sea level rise, because it reflects only the mean sea level, not the reach of waves and storm surge, which could be considerably higher and would be the relevant measure of impact, possibly driving the adoption of strong coastal defense measures or phased retreat a much earlier stage than the actual inundation under mean tide conditions.

These numbers disclose a major difference in both regions' urban growth patterns: while around the Tagus Estuary, urbanization took place mostly outside the flood plain, around the SF Bay urban encroachment, including vast urban areas and major infrastructure, have been built over landfill (Okamoto 2011, Luken 1974), and are located within a couple of meters above current high-tide (Hanak 2012: 52). In Chapter 2 we argue that this pattern can be traced to the evolution of legal standards and the actual praxis of land-use planning and landfilling, which varied greatly between both estuaries.

To this day, the Tagus Estuary enjoys a greater level of protection for lands located above high-tide, with protection equivalent to that afforded by the Public Trust in California extending up to the Highest Astronomical Tide, from which another 50m inland is included in the Public Domain. Therein, all new construction is forbidden, and it is additionally strengthened by a limited planning mandate for the adjacent 500m buffer, with strong restrictions on building outside existing urban perimeters.

Sea-level rise is being introduced in estuarine planning simply as an elevation above the high-water standard, but will, according to the National Water Law, force an expansion of public mandates with the rising waters. The SF Bay, besides being already much more encroached by a ribbon of levees, infrastructures and urban areas, is protected by a more limited planning mandate, which coincides with the limits of the Public Trust. That is, it extends up to the Mean High Tide. The BCDC has an additional limited planning mandate for another 30m inland from that line, but with no police power except for the assurance of public access in new development. Because region-wide planning bodies have no mandate above current high tide, the only way to limit development in low-lying areas is to rely on tools such as FEMA flood risk maps. These have an indirect power to deter development, through influencing municipal zoning codes and through the deterrent of high flood insurance premiums in exposed areas.

3.4 Discussion

3.4.1 Land use challenges in face of rising seas

Although both estuaries experienced severe impacts from anthropogenic action, the differences in the scale and, especially, the timeframes over which those impacts were made, resulted in diverse outcomes.

Around the SF Bay, landfilling was concentrated over a single century, between the mid-1800s and the mid-1900s. Although the definition of Public Trust in the US would theoretically preserve tidal lands from alteration (Swanson 1975, Chapter 2), an initial push to attract new settlers to the newly incorporated State of California saw wetlands being auctioned with full property rights, first for farmland, then for salt ponds. Throughout the first half of the 20th century, city governments opened low-lying lands adjacent to the shoreline to industry, commerce, and residential areas (Luken 1974), developments that are now highly vulnerable to even modest rates of SLR. While large areas of wetlands lost to salt ponds are being restored, the majority of former tidal wetlands remain encroached by urban areas and infrastructure, such that landward migration of tidal wetlands is not possible. Continued reduction in sediment supply to SF Bay (Schoellhamer 2013) may impair the ability of wetlands to keep pace with SLR merely through accretion (Orr 2003, Stralberg 2011, Swanson 2013). Therefore, identifying alternate paths for future wetland migration may be crucial for future wetland sustainability (Interviews 5, 8 and 11).

In contrast, the Tagus Estuary experienced progressive alteration over 2 millenia, during which time there was an incremental introduction of protection measures, derived from medieval traditions and the protection of the Crown's trust over fisheries and navigable waters, which in turn can be traced to Roman, Visigoth and Islamic traditions (Beirante 1998, Chapter 2). Having been expanded by 1864 to the protection of all beds and shores up to the HAT line+50m (the Public Domain), this already high standard was complemented in the past three decades with legislation specifically protecting wetland habitat and a planning mandate over a transition (adjacent) zone (established, for the Estuary Plan, at a further 500m inland from the Public Domain).

The result is that very few buildings now exist in former estuarine lowland. Most historically reclaimed land is still reserved for agriculture, with modern landfill reserved almost exclusively for port areas and a few industrial plants. The bulk of lands directly exposed to early stages of SLR is thus composed mostly of farmlands created through the draining of wetlands, the *Lezíria*. The remaining natural wetlands are expected to migrate and accrete, with deposition of sediment from suspended sediment loads that remain high, though reduced from pre-dam levels. Studies on specific sites indicate they will cope with SLR expected by the end of this century (Duarte 2013, Silva 2008, Silva 2013). Because most Tagus Estuary wetlands are flanked by agricultural lands, it should be possible for these wetlands to migrate upland with rising seas (Titus 2011), without the complications that would ensue along urbanized shorelines with multiple landowners.

Thus, SLR arguably poses a much greater threat to SF Bay than to the Tagus Estuary. Around SF Bay, there is a greater awareness of potential impacts and more involvement of civil society in efforts specifically addressing SLR (Heberger 2009: 43, 57, 71, 79, Interviews 2, 7, 8, 11), whereas in Lisbon the issue tends to be addressed within the context of integrated environmental planning or municipal risk management (Interviews 1, 3), and not as a separate issue.

3.4.2 San Francisco Bay Plan and environmental governance

The environmental planning frameworks and governance structures for both estuaries are very distinct and present both advantages and drawbacks.

In reaction to the scale and rapid rate of environmental disruption in SF Bay, a strong environmental movement emerged, with new laws and agencies tasked with nature protection, adding to the complex of public agencies with very specific and narrow mandates. The multiplicity of agencies and their often overlapping, sometimes conflicting jurisdictions, results in a decision-making process for environmental management of the SF Bay that is intricate, slow, and marked by efforts to defend existing mandates. However, the highly scrutinized planning process yields transparency and public awareness over the planning efforts and their results. There is a strong emphasis on a well-grounded, and heavily negotiated, formulation of regulatory and planning documents. The defense of mandates may inspire innovative solutions for adaptation that do not interfere with the jurisdictional status-quo, including establishment of specific partnerships dealing with the execution of a given project.

We believe the process that led to the recent Amendment concerning Climate Change serves as a good proxy for the peculiarities of the environmental planning process in California and, more broadly, the United States. What was included in the Amendment was severely limited by the virtual impossibility of expanding existing mandates and jurisdictions beforehand. In fact, throughout the process, great effort had to be put into reassuring stakeholders that no "power grab" would be attempted, and even existing and solidly established mandates had to be reasserted. It became clear from early feedback that some entrenched positions from interest groups and local governments would compromise any solutions falling outside current jurisdictions (Eichenberg 2013, Interview 2).

The protection by stakeholders of their own jurisdictions and interests has limited the possibility of expanded environmental protection mandates for institutions such as the BCDC. Perhaps the most obvious illustration of this is the limit of BCDC jurisdiction to a strip of land 100-feet (30-m) from the current shoreline: it stands to reason that the areas inland from this narrow coastal strip would need to be managed in anticipation of future sea-level rise and landward transgression of the shoreline. Being located just above current storm surges, they are extremely susceptible to even small increases to SLR (Hanak 2012). Yet, the final document of the Amendment, while for the great part consensual, had to be confined to the bounds of an environmental planning mandate emanating from the mid-1960s, at the dawn of the current environmental standards, according to a much more limited understanding of the environmental processes involved, and at a time when the threat of sea level rise had not yet been fully assessed.

The collaborative planning effort was very successful in articulating (or, rather, navigating) strongly opposed perspectives on development priorities for the SF Bay's shorelines. Yet, the limited power of the main coordinating agency to enforce more ambitious planning objectives may be perceived as a partial failure of the legislature to re-shift the power balance to reflect the evolving challenges posed by greater environmental awareness and the threat of SLR to man-made and natural infrastructure.

The weakened position of the coordinating agencies renders them less capable of balancing competing interests. It should be noted that, to adequately pursue their mandates, this balance should not be established at, or even near, the least-common-denominator stances. Some stakes may not hold equal bearing, especially if they necessarily subvert or undermine the plan's objectives: being fair in the treatment of competing stances does not equate to recognizing them all as valid. This was a major issue with the CalFed initiative (water management in the Sacramento-San Joaquin Delta, just upstream from the SF Bay) where federal and state agencies cooperated with local agencies and stakeholders. Despite being deemed as a success in collaboration and consensus-seeking (Fuller 2009) the planning effort was less successful in achieving the desired policy ends (Bobker 2009) and ultimately failed to adequately protect the common resource it aimed to protect (Hanemann 2009).

The expansion of planning mandates to the shoreline adjacent to the existing jurisdiction, while unpopular among developers and some city governments, would allow BCDC and other agencies to have much greater capacity to deter increased exposure to SLR inundation, namely through limiting further development of existing landfills, and encouraging non-structural coastal defense solutions. As BCDC's mandate regarding waterfront development beyond the high-tide line is limited to little more than an "advisory" role and the enforcement of public access within existing or proposed development areas, the amendment does not really provide the mechanisms to significant change to the way urbanized shorelines evolve. It does compensate this with a very clear definition of how its mandate will be pursued within the areas where it indeed has a more active planning mandate (especially in wetlands and salt ponds), and provides an extensive list of solutions, some of which are very innovative, which all entities intervening on the shoreline are encouraged to consider.

Among the several items listed, are included solutions for coastal defense that are less damaging to ecosystems or design solutions that may increase the resilience of new urban areas. The limited ability to enforce more ambitious solutions, which would require an expansion of mandates, could be partially compensated by clear judicial decisions regarding the interpretation of existing jurisdictions. Two such decisions could come through the upholding of the ambulatory jurisdiction over the Public Trust: given the doctrine regarding the Trust and the provisions regarding erosion and avulsion, a progressive flooding of the shore would lead to a corresponding redefinition of the high-water line. Even limited clarifications over jurisdictions and mandates, as is the case with BCDC's hypothetical claim to the "ambulatory nature" to its public trust doctrine – albeit already asserted in the past by court rulings, as mentioned by Eichenberg, (2010: 263-264) – or the expansion of its planning mandate over areas located above mean-high tide, are unfortunately likely to face fierce opposition and litigation from interest groups and municipalities (Fulton 2012: 92).

The Bay Plan is comprehensive and accurate in its depiction of the best state-of-the-art knowledge regarding SLR adaptation and the range of adaptive solutions that may be considered. Finally, through painstakingly assuring all stakeholders and agencies involved are confident that the resulting regulations are sound, the Plan's complex and limited formulation is likely to lead to a much swifter and uncontroversial implementation.

3.4.3 Tagus Estuary Management Plan and environmental governance

The Tagus Estuary Plan is the last planning element resulting from the incorporation of the European Water Framework Directive into Portuguese national law. It will, once approved, coordinate environmental management and water and shoreline uses in and around the estuary. Therefore, it sets the blueprint for the integrated management of the Estuary. The planning process built on the efforts conducted by the Administrações de Região Hidrográfica in the creation of Coastal Management Plans, and retained a strong emphasis on inter-agency collaboration and holding public meetings so as to divulge the plan and its objectives and encourage a more active public participation (as compared to what was the previous Portuguese planning practice).

Nevertheless, and undoubtedly in large part due to the limited tradition of public participation, most of what actually went into the plan was the result of direct talks between the public agencies most vested in the Estuary's management (the ARH, later merged into APA, the Port of Lisbon, and the Nature Reserve) with consultation of municipalities regarding site-specific issues. The collaboration between agencies was unanimously mentioned as a very positive aspect of the planning process, and allowed for several strategies to be coordinated, namely those regarding dredging, the delimitation of SLR-induced flood maps, or the creation of clear standards for the protection of all wetland habitats around the Estuary, with the identification of priority interventions. What was achieved is actually a sound environmental management plan backed-up by strong and recently expanded environmental protection mandates and jurisdiction.

The final stages before the Plan's final approval, though, have been marred by two issues, which could be seen as relics of the previous paradigm of top-down, deterministic, planning. The first is that, following a change in government and the reorganization of the Portuguese Environmental Agency, the ARH was absorbed onto a much larger institution and lost much of its recent capacity to directly engage stakeholders and lead the planning process as a mediator. Concurrently, and perhaps also bearing some relation with the Plan's delayed publishing, is the outcry which followed the top-down deterministic decision to build the new container terminal, taken without consultation of the planning parties. More recently that proposal was abandoned and the possible location of the deep-water container terminal on a former industrial complex, in Barreiro, is now being studied. The Plan has, as a consequence, been left in a limbo, pending final approval for over two years.

3.5 Conclusions

Both the SF Bay and the Tagus Estuary are faced with the eminent threat from SLR, and therefore are already working on the introduction of adaptation solutions and adaptive governance structures onto their respective environmental planning instruments. Their ability to successfully respond to the challenge and incorporate new planning frameworks and standards is a function of their past traditions and current institutional and legal structures.

The SF Bay Plan can only limit development within a narrow strip above the present mean high tide line, which is too limited to adequately address future sea level rise. Landward migration of tidal wetlands cannot be facilitated because the plan cannot prevent development in low-lying areas just above the present mean high tide line. The Bay Plan's Climate Change Amendment resulted from a very successful collaborative effort to reach a consensus, but the price of consensus was no real extension of the coordinating agency's mandate or jurisdiction. As stakeholders adopt entrenched positions, the resulting "least-common-denominator" solution may be inadequate to face the future challenge.

The Estuary Plan is the result of a strictly top-down planning framework and therefore depends on the will and drive of a handful of government agencies to see it through. The lack of involvement of many stakeholders reduces the accountability of decision-makers. Moreover, over-dependency on strict hierarchy may lead to unilateral decision-making, such as inclusion of a new deep-water port, which was strongly rejected by stakeholders and much of the public, thereby forestalling adoption of the document as a whole. Greater engagement of the civil society in the planning process could have avoided the current stalemate.

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4 EMERGING CONFLICTS IN IMPLEMENTING GREEN SEA LEVEL RISE ADAPTATION: THINK GLOBALLY, SOLVE LOCALLY?

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4.1 Introduction

At a time when several countries are adopting increasingly ambitious climate change mitigation strategies, often levered on the curbing of greenhouse gas emissions, the introduction of local adaptation measures is perhaps less consistent. Sea-level rise adaptation, while being a seemingly unavoidable attitude in face of one of the most pervasive, and indeed already noticeable, impacts of climate change (IPCC 2014, NRC 2012, EEA 2012a, Church 2008), is often addressed at the local scale with uneven results.

Awareness of potential losses along more exposed coastlines is increasing with the publishing of studies and increased media coverage, especially following natural disasters (IPCC 2012, Carey 2011, Tollefson 2012, Wenger 2015), although not always in the most effective or precise manner (Hulme 2009). Yet, most vulnerable shorelines still lack a coordinated effort in articulating adaptation strategies and site-specific interventions.

Complexity of local adaptation

Local adaptation lends itself to new challenges, posed by the peculiarities of local government/governance, and the multiplication of private actors and interest groups. Several environmental policies are typically adopted at a national scale, and then must be implemented at the local level by multiple agencies. Therefore, the success of implementation depends not only on the strength of the national commitment, but also local governance (Douglas 2014). The impacts of climate change are "displaced across scales and do not adhere to conventional governance boundaries" (Steele 2014), and alternative solutions for climate adaptation in urban contexts are often expensive, affect the rights of private property owners, may require major changes to existing planning systems, and constrain future property development options (Bulkeley 2013).

This increased complexity is made all the more difficult to address because of the limited resources local governments often have at their disposal. Past decisions made by local governments now earmark significant portions of their budgets to the maintenance of aging infrastructure and constrain alternative investment options, and "path dependence" makes institutions reluctant to change past ways of doing business, even in face of new requirements such as the need to articulate multiple scales and an ever-increasing number of actors and interest groups (Matthews 2015).

Within the modern "sanitary city", each of the specializations, "sanitation, street services, planning – works in a bounded realm informed by specialised competences siloed into departments and agencies" (Pincetl 2010: 46). Because of their "centralized, rigid infrastructures, many sanitary cities exhibit limited capacity to accommodate sustainable adaptations and practices" (Childers 2014). Thus, it can be difficult to work across specializations and establish the new governance platforms required to coordinate the definition and implementation of adaptation solutions.

The expanded role of local governance

This should not be dissociated from an expanded role of local governments and, especially, local governance/collaboration platforms, often including several local actors, ranging from interest groups to environmental NGOs and individual citizens. In the past, deterministic political decisions from centralized government institutions were perceived as "the appropriate, legitimate and unchallenged vehicle for social change, equality and economic development (…) responsible for environmental protection" (Pincetl 2010), a role that came into question as social movements addressed the lack of accountability and transparency of that model (Graham 2001). Regional or local governance has taken up a big part of the role formerly performed by centralized government agencies. Governance can, and should be, led by government or regional public agencies, as they hold a coordinating role and should be able to balance competing interests (Pierre 2000).

While the increasingly collaborative decision-making process is certainly beneficial in terms of the transparency of planning efforts and budget decisions, we would highlight three issues that may remain undervalued: non-profits are often treated as proxies for residents' interests where that may not always be the case (Pincetl 2010), leading to a further disenfranchisement of the local community; private interest groups may exert an undue influence over the outcome of the process through a disproportionate capacity for lobbying and, through litigation, intimidation of other stakeholders; and the outcome of consensus-seeking in collaborative decision-making may in some cases result in a "least common denominator" type of solution that, while acceptable to all parties, may fail to address the issue at hand (Hanemann 2009).

In the case of the United States (Svensson 2006) and, more specifically, California, the added complexity of the legal and institutional arrangements surrounding adaptation and local planning makes for a puzzle of overlapping jurisdictions and often unclear mandates (Fulton 2012). The San Francisco Bay Area is home to over 100 local governments and just the South SF Bay shorelines, where most case studies presented ahead are located (Figure 14) are split between 4 counties (San Francisco, San Mateo, Santa Clara and Alameda), 22 cities, 3 unincorporated territories, 3 flood control districts, and a multitude of city departments and special districts dealing with flood control, floodplain management, and infrastructure maintenance. Adaptation and planning efforts risk becoming a "stovepipe system" due to a propensity towards narrow mandates and the multiplication of single-purpose partnerships, where lack of communication and articulation of efforts among agencies may lead to a duplication of efforts and loss of efficiency.

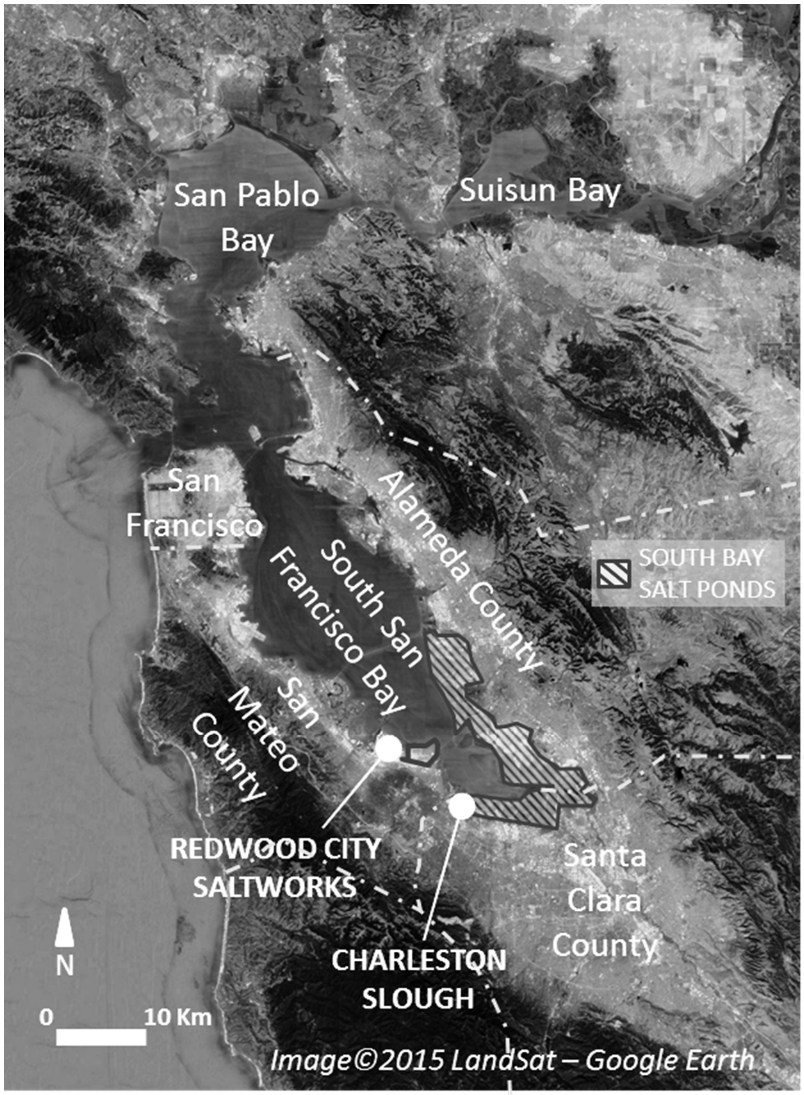

Figure 14 – Map of the San Francisco Bay, with locations mentioned in text.

Emerging conflicts in local adaptation: intractable conflicts or intractable stakeholders?

As quite a few of these adaptation strategies have very concrete territorial expressions, land-use conflicts often arise once they hit the "real world" The regulatory and legal implications of local adaptation are exacerbated by the specificities of land-use policy and property rights. Only during the implementation of specific solution do many of the clashing stakes and more or less serious conflicts arise. Given that many land-uses are incompatible with flood management and environmental protection, decision-making often entails one or more of the stakeholders having to forfeit their current or future stakes. Thus, entrenched positions regarding relocation of uses, limits to future property and building rights, or the allocation of resources (economic or otherwise) are prone to generate "intractable environmental conflicts" (Campbell 2003, Gray 2003, Castro e Almeida 2013).

These are types of conflicts where the entrenched opposition between some of the stakes results in the near-impossibility of reaching a negotiated solution. While there is a tendency to recognize all stakes as valid, especially within collaborative planning platforms, we suggest that that is often not the case. Rothman (1997) described a four-step framework for addressing conflict, which included a "resonance stage", where the "why" and "who" of the issue, according to all parties, is examined: as the needs of the various parties are the underlying causes of the conflict and, by having all sides hear the concerns of the other actors, it is expected that they might be able to identify possible points of convergence, and thus expedite a solution. This is perhaps an overly-optimistic perspective on the motivations of actors, as it assumes all stakes as legitimate.

Curtin (2005:88) characterized five different types of stakeholders, one being the "intractables", or those intractably opposed. We would go further: some stakeholders may be intractable simply because they have nothing to lose in the process, but a whole lot to gain: Land with no prior development rights is naturally cheap; if development rights are conferred onto that same tract through a judicial decision or a change in zoning or detail plans, the potential profit for the property owner/developer would be exponentially increased, while not being granted development rights is of absolutely no interest to the developer. Therefore, some apparently intractable conflicts could be attributed simply to the intractability of one stakeholder with an unreasonable expectation.

Analyzing specific case studies where local adaptation to sea-level rise is already underway, may provide good insights over the potential obstacles faced by the actual implementation of sea-level rise adaptation solutions at the local scale, and which are seldom fully addressed during the establishment of regional or national adaptation strategies.

4.2 Materials and methods

We conducted an in-depth research into three case studies, all located in the San Francisco Bay, California, USA (Charleston Slough, Redwood City Saltworks, and the implementation of "ecotone zones" on the South Bay Salt Ponds). The selection of the case studies was informed by a set of interviews with stakeholders and experts conducted during previous research by the authors.

For each case study, we analyzed documentations and publicly-available reports, as well as Bay-wide pilot projects concerning the incorporation of wetlands into flood defense structures.

We complemented this with a thorough review of news media articles and published opinion or marketing, in blogs or official websites. Additional inputs from semi-structured follow-up interviews with policy-makers and environmental planning professionals in the San Francisco Bay Area provided up-to-date information on the current situation of each of the case studies.

For each case study, we describe the events leading to conflict, identifying main stakeholders, their stances, and major shifts in discourse and how it correlates to relevant events in the process.

4.3 Results

Most of the South Bay shorelines were, during the early decades of the 20th century, reconfigured into an expansive system of salt pond evaporators, consisting of multiple levee-fenced ponds, most of them built at the expense of salt marsh (Goals Project 1999). Leslie Salt, by far the largest of the companies operating these ponds, still owned over 21,000 ha of Baylands as late as the mid-70s (Luken 1974: 140, Okamoto 2011: 133). Several other structures, such as flood detention basins or the Moffett Federal Airfield, were also built over former Baylands.

The 60s and 70s saw much-improved environmental standards, deriving from new state and federal legislation and more rigorous interpretation of older standards. Among others, in less than a decade several legal statutes were approved, such as the Clean Water Act of 1972, complemented by the state's water pollution legislation, the state's Porter Cologne Act of 1969 (Okamoto 2011: 158-160) and the passage of the state's McAteer-Petris Act of 1965, through which the state legislators halted landfilling, increased scrutiny over dredging, and set-up the San Francisco Bay Conservation and Development Commission (BCDC).

With the ceasing of most salt production activity around the South Bay, Cargill Salt, which had absorbed all Leslie Salt ponds, entered a deal with the federal and state governments to sell most of their ponds. The 15,000 acres (~6000 ha) of ponds were purchased in 2003 for $100 Million, plus $143 Million in federal tax write-offs (Fischer 2007), with funding from the State's California Department of Fish & Wildlife (CDFW) and Federal US Fish and Wildlife Service (USFWS), and additional contributions from 4 private donors. The South Bay Salt Ponds Restoration Project (SBSPRP 2009, SBSPRP 2014, Patton 2002) constitutes one of the largest wetlands restoration projects in North America. The ongoing restoration efforts are coordinated by the state's Coastal Conservancy through a partnership including about 50 different entities, ranging from federal and state agencies to local city governments, special districts and private partners.

Local adaptation around the San Francisco Bay has focused on two main types of interventions: the upgrading of existing coastal defense structures, in articulation with evolving United States Army Corps of Engineers (USACE) standards and Federal Emergency Management Agency (FEMA) flood maps; and the restoration of wetlands. The later was perceived as a priority from very early on (Williams 2001), as the impounding, dredging, and landfilling of wetlands for development (Swanson 1975: 85) had reduced the regional provision of tidal wetlands to less than 10% of its early 1800s levels (Goals Project 1999, Williams 2001, Madsen 2007, HDR 2014).

Much of the restoration effort has concentrated on the establishment of salt marsh habitat on former salt ponds, through the tidal reconnection of the ponds. Slow sediment fixation typically allows for a natural accretion to occur, up to the point where marsh vegetation becomes established. Concerns with capacity of marshes to keep up with the rates of SLR expected towards the second half of the century have triggered studies into solutions that would permit future migration, or at least promote marsh accretion.

Given that virtually all South Bay marshes are confined on their landward limit by landfills protected by seawalls, levees, and other coastal defense structures, the upgrading of these structures and wetland restoration efforts are, at least within the constraints of South Bay's land use patterns, increasingly assumed to be complementary, rather than opposed, strategies: ecosystem-based (or green) approaches to flood management may help improve the protection, cost-effectiveness, and co-benefits of levees (Wenger 2015, Battalio 2013), with wetlands instilling them with a level of flexibility and natural adaptability absent in strictly man-made structures, while at the same time providing an added wave attenuation capacity(Lowe 2013).

Through its past experience in marsh restoration and ongoing projects, the San Francisco Bay is an early adopter and leading research center for this type of green adaptation solutions. Comparable solutions are known in the region by different names, most notably as horizontal levees, (Battalio 2013, Lowe 2013, Zimring 2015), or as transitional wetland-upland ecotone or upland transition zones (Goals Project 1999:A-56, PWA 2004, ESA-PWA 2012, HDR 2014).

4.3.1 Adaptation studies and programs in the San Francisco Bay Area

The complex institutional framework has already addressed the threat posed by SLR through numerous documents, reports and pilot projects, led by all levels of government and through several multi-level interagency partnerships. Many of these studies focus only on the outlining of regional adaptation strategies or propose preferable courses of action, but there are an increasing number of programs leading into actual implementation of SLR adaptation solutions. Following are a few examples.

Federal Level

Federal agencies and regulators often engage in more direct collaboration with local governments in the design and implementation of projects, with the USACE, Environmental Protection Agency (EPA), FEMA, USFWS or NOAA, being present with varying degrees of involvement in several planning, restoration and flood protection projects (ACFCWCD 2015). The National Research Center published a report on the expected impacts of SLR in the Western states (NRC 2012) and USACE's San Francisco District is leading the South San Francisco Bay Shoreline Phase I Study (HDR 2014).

Partnerships between federal, state, and local institutions

Several multi-level partnerships between local, state, and federal agencies have worked on specific projects or in publishing SLR adaptation studies and reports. "Adapting to Rising Tides" (BCDC 2015a) is an ongoing project focused on SLR vulnerability and risk assessment and adaptation along the Alameda County shorelines, and results from collaboration between the federal National Oceanic and Atmospheric Administration (NOAA) and the BCDC, a state agency. The San Francisco

Estuary Partnership (SFEP), a multi-level agency coordinating restoration actions at the regional scale, spun-off from EPA's National Estuary Program, to promote inter-agency cooperation and facilitate the identification of public and private grants and other funding opportunities. SFEP is one of the leaders in the Bay-wide Flood Control 2.0 program (SFEP, n.d.). Another example of these multi-level partnerships is CHARG - Coastal Hazards Adaptation Resiliency Group (CHARG 2015).

State level
Quite a few studies on the impacts of SLR have been produced or sponsored by the state's legislators and agencies, such as "A Slow Moving Emergency" (Gordon 2014), by the California State Assembly Select Committee Sea Level Rise and the California Economy, or the 2013 report "The Impacts of Sea Level Rise on the San Francisco Bay" (Heberger 2013), which focuses specifically on the SF Bay.

The BCDC, tasked with the protection of the San Francisco Bay, has published several reports on the topic, such as the Living with a Rising Bay report (BCDC 2011a), and has recently amended the Bay Plan, guiding the protection and regulation of uses within the Bay's Public Trust, so as to reflect the latest knowledge regarding SLR (BCDC 2011b).

Local level
Santa Clara County established a local partnership to expedite implementation of local climate adaptation measures across city borders, the Sillicon Valley 2.0 (SCC 2015). The San Francisquito Creek Joint Powers Authority, is an example of the complex partnerships that are often purpose-created in the region, coordinating efforts from two counties (San Mateo and Santa Clara), three cities (Palo Alto, Menlo Park, and East Palo Alto), and two regional water agencies (Santa Clara Valley Water District and San Mateo County Flood Control District) within a watershed that straddles the boundary between them. It is the local sponsor in the USACE's San Francisquito Creek General Investigation Study.

The City and County of San Francisco has its own Floodplain Management Program (CCSF 2015) and is upgrading its standards to address SLR. Other cities have their own SLR studies and plans, such as the City of Palo Alto's Threat and Hazard Identification and Risk Assessment (OES 2014) or the City of Mountain View's Environmental Sustainability Action Plans 1 & 2 (CMV 2009, 2012).

Several environmental NGOs and public/private partnerships have established programs to promote environmental protection and research green SLR adaptation solutions. The San Francisco Estuary Institute (SFEI), a science institute dedicated to aquatic studies for the Bay, has been pioneering research on innovative SLR adaptation solutions, especially regarding the incorporation of wetlands in the mix of coastal defense solutions. Among the more active NGOs are Save The Bay, The Bay Institute, The Nature Conservancy, and the Audubon Society.

4.3.2 Charleston Slough

Figure 15 maps Charleston Slough and its surroundings. Numbered references in the text refer to this map.

The Inner Charleston Slough (ICS), along the border between the cities of Palo Alto and Mountain View, in Santa Clara County, was separated from the Outer Charleston Slough by a berm (1), built by the Spring Valley Water Company in 1923. It was tidally connected to the Bay through a 60-in (~1.5 m) culvert, and thus hosted tidal marshland. After much stricter limitations on pollutant and sewage emissions onto public waters were enacted in the 1960s and early 70s, the bi-products of salt production could no longer be directly disposed of into the Bay. Leslie Salt, the owner of the Slough and adjacent salt evaporators, resorted to storing salt brine in ICS, and cutting off the existing tidal connection with the Bay by replacing the existing culvert with a smaller one, at a higher elevation (1). The continuous water impoundment led to most of the vegetation being killed off by prolonged submergence (Hydroikos 2001).

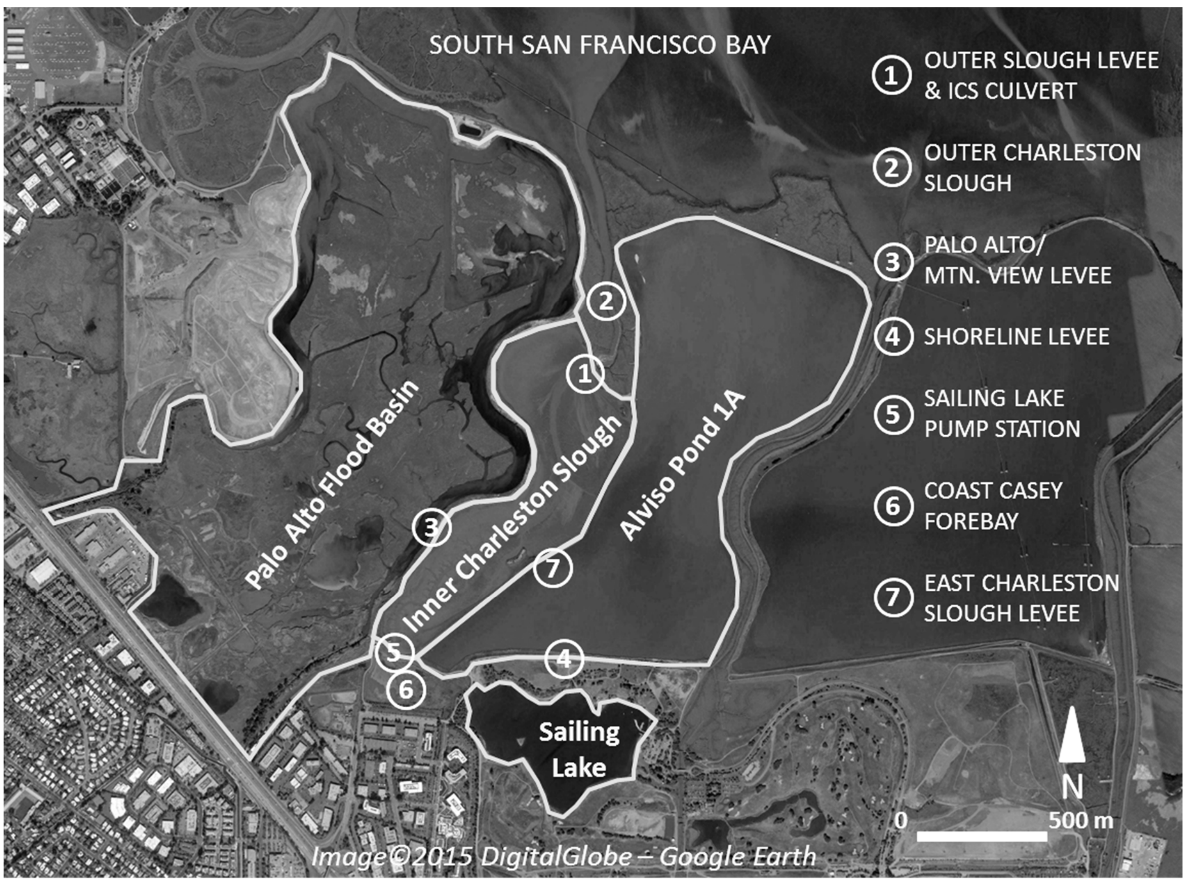

Figure 15 – Map of the Charleston Slough and surroundings.

BCDC had introduced, in its Bay Plan, the provision for a "zero-net-loss" policy for Baylands and marshes. As such, the killing-off of ICS's marshes was seen as a violation of McAteer-Petris Act. As soon as BCDC was made aware of the unauthorized culvert replacement and its consequences, it required Leslie Salt to restore the ICS to full tidal action and ensure the fixation of 40 to 60 acres of tidal marsh. (BCDC 1999)

Leslie Salt proposed to convey full property of the ICS to the City of Mountain View, which would inherit the responsibility for restoring the marsh. In 1978, Leslie Salt operations were taken over by Cargill, which kept the tidal gates shut. In 1980 the City of Mountain View took title of the ICS and proposed an amendment to the restoration scheme: rather than fully restoring tidal action, the City proposed to introduce a water control gate, allowing for a daily tidal range of 0.85 to 1.10 ft. This reduced fluctuation would dispense further upgrading of the levee protecting the Palo Alto Flood Basin (3). BCDC authorized this through an amended permit, as long as the City ensured at least 30 acres of marsh would establish within 7 years. The new gate never worked properly and the insufficient tidal range in the ICS impeded the fixation of marsh vegetation (BCDC 1999).

To comply with BCDC's permit, the City started working on a new restoration plan in 1988. Finalized in 1996 (McCabe 1996) and implemented through to January 1998 (Hydroikos 2001), the project replaced the gate with six self-regulating culverts at a lower elevation (therefore enhancing tidal fluctuation in the ICS) , raised the levee between the Inner and Outer Sloughs (1), and slightly upgraded the lower levee separating the ICS from Cargill's Salt Pond 1A (7), to the east.

As the 7-year timeframe for the establishment of marsh vegetation had not been met, BDCD now pushed for the full restoration of 53 acres of vegetated tidal marsh. The tidal range, while much greater than before, was still over a foot less than predicted, and thus unable to provide ideal conditions for the accretion (elevation build-up through the natural fixation of sediment flooding in from the Bay) and spontaneous colonization by salt marsh vegetation. Additionally, early colonization by an invasive species of cordgrass required the use of pesticides in 2006 and 2007 and the desirable native cordgrass has proven difficult to recruit (Coats 2012). As the achievement of the 53 acre goal appears to be taking far longer than expected, the BCDC has been requesting further action from the City, which would plausibly include the requirement of full tidal reconnection between the Inner and Outer Slough so as to expedite marsh expansion, as per the original permit (BCDC 1999).

In the meantime, adjacent tracts have seen much change (Figure 15). To the West, the former Mayfield Slough has been transformed into the Palo Alto Baylands/Palo Alto Detention Basin, a regulated pond with significant areas of salt marsh which doubles as an essential flood detention basin protecting the City of Palo Alto. South of the ICS, and separated from it by a wide levee (4), is the Shoreline Park, Country Club, and the Sailing (or Shoreline) Lake, all built over landfill and experiencing significant subsidence.

To the East, Salt Pond A1 was transferred to the Salt Bay Salt Ponds Restoration Project (SBSPRP). SBSPRP has plans to open Pond A1 to full tidal action (SBSPRP 2014), and has proposed to include Charleston Slough in the project by opening a breach in the levee separating them (7). The City of Mountain View is concerned this may lead to a very fast flushing of the already significant sediment that has built-up in the ICS, as the Pond A1's base level is currently several feet below that of the ICS. As such, achieving BCDC's restoration goals within the ICS would likely prove impossible for several years after that reconnection. To further complicate matters, this tidal reconnection would mean that the levee protecting the Shoreline (4), as well as that separating ICS from the Palo Alto Basin (3), would then be exposed to full tidal action, whereas now they are buffered by the managed ponds. This would require extensive upgrading, especially in the case of the Shoreline levee (4). With sea-level rise already forcing the revision and expansion of flood protection standards around the Bay, the upgrading would have to meet much stronger requirements than those that led to its initial creation.

A seemingly more trivial issue, but one likely to produce significant public outcry, is that the Sailing Lake, a purely recreational manmade lake within the Shoreline Park, is sustained by daily replenishment through a pumping station located at the southwest end of the ICS (5). If the Slough is tidally reconnected, it is more than likely that the pumping station intake would have to be relocated or reconfigured if the Lake were to be maintained at its current water circulation level.

With so many conflicting interests, and such a large number of federal (USACE, EPA, USFWS, FEMA), state (BCDC, CDFW, Coastal Conservancy), and local (City of Mountain View, City of Palo Alto, Santa Clara Valley Water District) agents involved, it is no wonder that the decision-making process may appear untenable at times.

Nevertheless, there are already direct communication lines between several of the involved parties that prove invaluable in achieving these goals. Although only held once a year, bilateral or multilateral forums, such as the yearly SBSPRP Regulatory Workgroup Meeting, address the negotiation of mutually-beneficial solutions (Interview 13).

The City of Mountain View is comfortable with the possibility of having the ICS tidally reconnected, but obviously only if the BCDC is in agreement with the solution and thus lifts, or extends, the deadline for reaching the current marsh restoration goal within the ICS. The City is equally worried about potential impacts over existing flood protection structures and, especially, with potential liability over a weakened protection provided by the levees separating the ICS from the Flood Basin (3) and the Shoreline (4). It would likely struggle to reach a solution where the costs of upgrading those structures and finding a solution for the pumping station would be shared among the interested parties.

SBSPRP is interested in achieving the maximum benefits in terms of habitat provision from the restored ponds (Interviews 8, 11, SBSPRP 2014). By combining the already-planned tidal reconnection of Pond A1 to the Bay with the breaches that would also reconnect ICS to full tidal action, the medium- to long-term potential would be greater (although relatively small, incorporating ICS would significantly expand the total area available for immediate restoration in the Western Alviso Ponds). The BCDC has remained consistently adamant in its requirement that the 53-acres of restored marsh goal be met within the limits of the ICS, and has expressed so to the City before.

Nevertheless, recent information (Interview 13) points towards the possibility of a mutually-beneficial, if slower and more complex, combined restoration of Pond A1 and ICS, contemplating equally an upgrading of the Shoreline and Palo Alto levees.

4.3.3 Redwood City Saltworks

The bulk purchase, in 2003, of Cargill Salt Ponds, mentioned above, left out a few areas. One such tract was the Redwood City Saltworks (Figure 16) which, at the time, remained an active salt production facility. In 2007, David Benjamin, a state administrative law judge found the 2003 valuation of the South Bay Salt Ponds ($100 million in cash and $143 million in federal tax write-offs) to be largely based on “unfunded assumptions” during the land’s appraisal. One such assumption the judge found inflated was the valuation of the 350 acres around Cargill's Redwood City plant at $78.5 million. This presupposed a development plan of thousands of new apartments, stores and office buildings. The appraisal failed to highlight that such a valuation was conditional to such a development being permitted which, as we will discuss ahead, is very far from a given. The judge thus concluded that the appraisal "provide[d] no factual basis on which to conclude that it is reasonably probable that the public agencies would permit the proposed mixed-use development."» (Fisher 2007).

Coincidentally or not, Cargill announced in 2006 its plans to phase-out salt production in Redwood City and partners with a developer, DMB, in outlining the future of the Saltworks. DMB mass-mailed all Redwood City residents encouraging them “to participate in the development process and asking for ideas on ways to use the 1,433 acres.” (Louie 2006).

Environmental NGOs, especially Sierra Club and Save The Bay, started contesting the proposed development as soon as DMB disclosed their “50-50 Balanced Plan Project Proposal” for the Saltworks, by renowned architect and urbanist Peter Calthorpe. A lead proponent of “Smart Growth”, mainly focused on compact, multifunctional, transit-oriented development, the architect published a defense of his project (Calthorpe 2009), in which he characterized the ponds as a “1,400-acre moonscape, a century-old industrial salt "factory without a roof" that could continue to make salt indefinitely.” This assessment is vehemently contested by the NGOs, which emphasized that, even in its abandoned state, the ponds provide valuable habitat, and lend themselves to full restoration as wetlands. Several bloggers and journalists picked up on the story in the following years, many of which emphasizing that the project prevented restoration of former wetlands (Shigley 2009, Jones 2010, Parman 2010).

During 2010, DMB campaigned heavily to have the project approved by the City’s planning commission or simply through a local ballot that would authorize the development (Elinson 2010). The debate and challenge to the project did not fade, however, and in the following years Save The Bay, BCDC, and Calthorpe, debated the future of the saltworks on several media, including a SPUR-sponsored debate. (Baume 2011). Following several concerns put forward during public hearings and the environmental review process (RCPC 2015), the Saltworks Project application to the Planning Commission was withdrawn in May 4, 2012 (DMB 2012).

Figure 16 – Map of the Redwood City Saltworks.

In 2014, Calthorpe mentioned in a radio interview that there was still room for a compromise that included development of the saltworks (KZSU 2014) and, soon after, DMB announced it was working on "a revised and "scaled-back" project that provides for restoration of the majority of the 1,400-acre property" (DMB 2015). Save The Bay has made it clear that they will keep fighting these development proposals (Lewis 2015).

Jurisdictional determination under the Clean Water Act

In the past few years, DMB has shifted its efforts towards attempting to exclude the Saltworks from under the purview of the federal and state regulations regarding wetlands and tidal waters. To achieve this, they are reconfiguring the project so that development is concentrated on the western-most portion of the site, that has been disturbed for longer (DMB 2012), and are trying to get a determination of no-jurisdiction under the Rivers and Harbors Act of 1899 (RHA) and the Clean Water Act of 1972 (CWA). Both are federal statutes protecting the Waters of the United States.

In 2010, a preliminary jurisdictional determination by the USACE found the site to belong to the Waters of the US, and thus subject to the provisions of the RHA and CWA (USACE 2015). Two years later, in May 2012, DMB made the bold move to forfeit further preliminary analysis and requested a final, and binding, approved jurisdictional determination of the extent of jurisdictional waters of the United States and navigable waters occurring on Redwood City Salt Plant project site. Save The Bay would later denounce this as an attempt to have the Saltworks declared as non-jurisdictional under the CWA (Lewis 2015): if successful, the move would exclude the land from the federal protection granted to the Waters of the United States and, at the same time, preempt most environmental objections to the project, especially those regarding the proposed dredging and filling of former wetlands.

The determination of jurisdiction under the CWA is shared by the USACE and the EPA. Typically, the EPA relinquishes its power onto the USACE. After initially doing so with regards to the Saltworks[23], the EPA elected on the last available date to make the final CWA jurisdictional determination. This uncommon decision was made after the EPA learned from the USACE that it would allow the exemption, under a "confirmed no-jurisdiction" determination, regarding both the CWA and the RHA, thus reversing its own 2010 preliminary decision (USACE 2015). USACE discussed at length, in its memorandum regarding the binding RHA decision and the proposed ruling regarding CWA and the attached legal principles (Stockdale 2014), that most of the eastern portion of the site had been historically above Mean High Water (MHW), even where the previous land cover had been tidal salt marsh, and with the exception of a couple of double-sided sloughs, all land was considered outside RHA jurisdiction by having been above MHW at one time. While making it clear that the CWA jurisdiction is a distinct question from the RHA jurisdiction, the Corps concludes that the liquid pickle and bittern on the site is not "water", as it does not clearly fall within any of its seven categories of "waters of the US). Therefore, it argues that these liquids are not subject to CWA jurisdiction. It further dismisses the possibility of determining jurisdiction on the basis of the land being composed entirely of former salt marsh stating that "the site has been highly altered to facilitate the salt manufacturing process. This alteration of the site and a century of industrial salt making have eliminated any trace of the prior marshland or wetland character of the site." Additionally, USACE argues that there is no normal flow of tide, that the liquids are intentionally hydrologically separated from the Bay's waters.

Being produced at the Washington, D.C. USACE headquarters, this legal interpretation was met with objections even by the Corps' own San Francisco District. It was by no means an uncontroversial assertion (Lewis 2015, Rogers 2015) as the traditional

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[23] In an email message dated 30 October 2012, the EPA stated that the Corps should follow normal procedures and make the approved jurisdictional determination (AJD) under both the RHA and the CWA.

assumption, based on Froehlke (1978) and others, is that the water impounded behind levees is indeed the same as the Bay's, and thus subject to federal protection. The level of disturbance and/or chemical alteration appears to have had no bearing on that precedent-setting decision, and has been invoked numerous times in land disputes around the Bay's shorelines.

While pending, this decision has been perceived as a major threat not only to the aspirations of environmental NGOs in having the site restored, but equally in establishing a potentially game-changing precedent for future land disputes (Silverfarb 2015, Speier 2015). It was also reported as a fight to uphold the standard of what constitutes Waters of the US under the CWA and, consequentially, wetlands subject to Federal protection and potential restoration (Rogers 2015, Myrow 2015).

EPA stepped-in immediately before the deadline for USACE's determination to be released, in April 18, 2015 (EPA 2015). Ultimately, the EPA may yet decide not to uphold a CWA jurisdiction over most of the Saltworks. Nevertheless, the simple fact that it asserted its right to rule on the matter (and, potentially, overrule the Corps' assessment) could easily be interpreted as an at least partial disagreement with USACE's assessment. The EPA is expected to make the final ruling early in 2016.

4.3.4 Adapting to adaptation: restoration standards require changes to Bay protection standards

As mentioned before, the South Bay Salt Ponds (Figure 14) is the largest wetland restoration project on the West coast of the United States (SBSPRP 2009, SBSPRP 2014). It is also costly, with early estimates for the complete restoration pointing to over $200 million, excluding contingency costs and the costs of acquisition (Patton 2002: 22). To qualify for state funding, several restoration actions proposed for Phase 2 of the project will have to be demonstrably resilient in face of SLR and, in the heavily-encroached setting of the South Bay ponds, that entails the inclusion of ramps along the shoreline where levees currently block wetland migration. These 30:1 ramps are a practical application of the "ecotone transition zone" concept mentioned above (Battalio 2013, Lowe 2013, Zimring 2015, Goals Project 1999:A-56, PWA 2004, ESA-PWA 2012, HDR 2014). The principle is that if the ramp is designed with a gentle slope within the tidal range, it will allow the creation of a fringe of salt marsh vegetation on the landward edge of restored ponds that may expand progressively through natural accretion as sediment slowly builds up on the tidally-reconnected ponds (Figure 17).

Additionally, these shallow slopes on the Bay-ward side of levees can be readily-incorporated into the design of the necessary upgrading of existing levees and other flood protection structures (HDR 2014). With the expected rates of SLR, most shoreline defense structures protecting the South Bay will require extensive retrofitting simply to keep-up to FEMA's 100-yr flood protection standard.

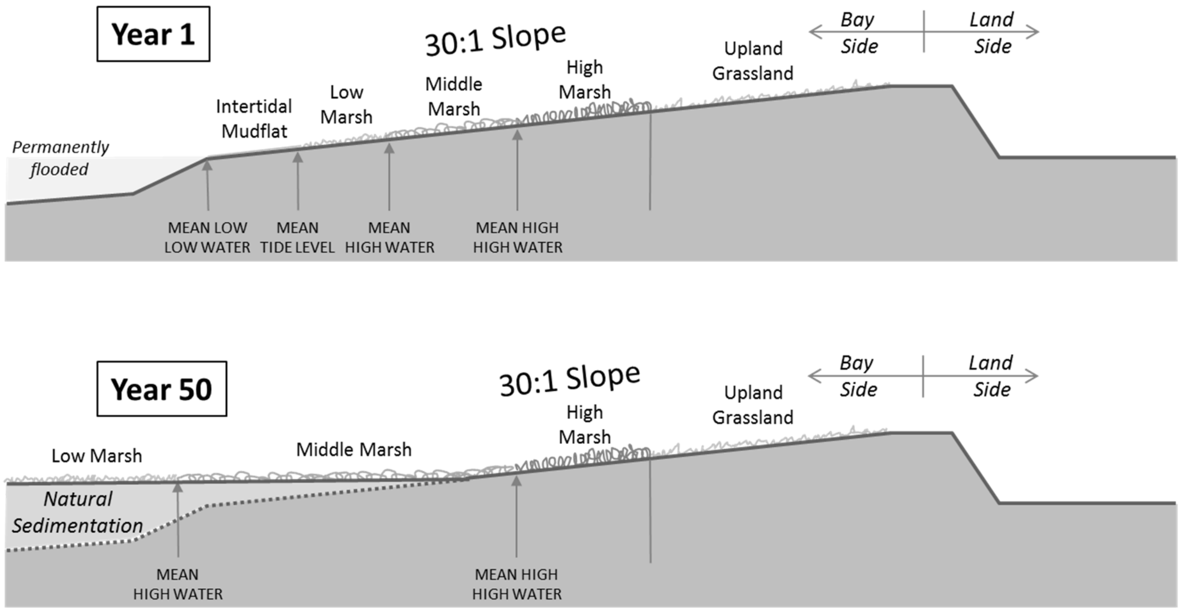

Figure 17 – Levee with ecotone zone (adapted from USACE2015: Figures 3.6-3 and 3.6-4).

BCDC's discomfort with rubber-stamping fill

These ramps, while well-received by most local actors (namely the project-leading Coastal Conservancy, but also USACE and flood control districts) technically constitutes an instance of Bay filling, as the 30:1 ramp requires some material to be deposited along the levee within the jurisdiction of the BCDC. Going back to this agency's original mandate, halting Bay fill was a foremost concern, as it had been responsible for the destruction of enormous expanses of wetland habitat up to the 1960s. It is therefore no wonder that the BCDC will thread carefully with regards to any alterations to its current "zero-net-loss" policy. Thus far, small pilot projects including ecotone zones, such as the Oro Loma test site (ESA-PWA 2012), have been permitted on a case-by-case basis and BCDC has been reluctant in accepting from the get-go the incorporation of ecotone zones in larger project sites. The agency is likely concerned that a rash adoption of a new policy regarding fill could open a loophole and usher in attempts to push through future projects proposing new landfill, unrelated to the restoration of wetlands.

Nevertheless, as the several stakeholders become more familiarized with the ecotone zone solution, there is the possibility that the agency will revise its policy regarding this very specific solution (Interview 13). It has begun the 18-month, NOAA-funded, Policies for a Rising Bay project (BCDC 2015b) through which BCDC's Commission Fill Policies Working Group will identify and eventually propose adaptation of the agency's guidelines regarding bay fill.

4.4 Discussion

The types of conflict emerging from local adaptation efforts around the San Francisco Bay may be organized into three major groups, based on the stakeholders involved:

conflicts between two or more public stakeholders, between public and private stakeholders, and between two or more private stakeholders.

4.4.1 Public vs. Public

Too many entities with overlapping jurisdictions and limited mandates may lead to the "stove piping" of agencies and departments. Without proper articulation, they may independently address the same issue and reach diverse solutions based on their narrowly scoped mandates and missions, which may enter in conflict during implementation (as was the case with Charleston Slough). Or, quite the opposite, it may equally lead to situations where all agencies take passive stances waiting for someone else to take the lead in tackling a given problem: too much involvement may lead to entropy, too little, to inertia.

Some of the overlap that would be apparent while looking at the regional scale, becomes less obvious once each area of the Bay is analyzed individually. For instance, while the federal EPA is taking a big role in the East Bay adaptation studies, coordinating directly with the Alameda Flood District, the South Bay adaptation efforts are mostly being coordinated by the state's Coastal Conservancy, even if they include several other state, federal and local agencies. The San Francisquito Creek Joint Powers Authority would be another example where, due to the site's location along the border between two counties, a partnership among adjoining municipalities and flood agencies was deemed more efficient.

While that is not always the case, all the examples analyzed include public agencies from at least three levels of government (federal, state, and local). The ample provision of inter-agency "task forces" or "partnerships" helps tackle many complex problems, but there is room for improvement. For instance, at its inception, BCDC was set up as a coordinating agency, and the Commission includes commissioners representing local governments, state and federal agencies, and even local interest groups.

Since the 1960s, though, quite a few other agencies have been granted mandates that would require coordination at the regional level, but bilateral communication is often reserved for infrequent meetings; in the specific case of the South Bay, this often means that relatively simple revision or conciliation of standards or proposed solutions may have to wait for a new scheduled meeting to take place. For some bilateral decision-making, this may represent a delay of several months. The rapidity of change and innovation in regional adaptation efforts would likely deserve a more permanent and regular communication platform so as to permit expedited coordination.

Two entities tasked specifically with the Bay's conservation may play an even more relevant role in the articulation and knowledge-sharing among the several public actors, SLR adaptation, and wetland restoration projects: The San Francisco Estuary Partnership could have a more active role in streamlining the articulation of federal and state funding, while the BCDC is, by its very nature, the prime coordinating entity for San Francisco Bay. As of late, the BCDC has been more associated with its regulatory role but that hasn't always been the case. Although its full planning jurisdiction extends only to the limits of the Bay's Public Trust (MHW), the BCDC has a dual body, with a permanent planning unit staff, but also a commission including in in its roster representatives from local governments, special districts, and state and federal agencies with stakes on the Bay and its shorelines. Reinforcing (or rather, restoring) the latter's role as the foremost coordinating and planning platform in the Bay may help reduce redundancy and increase efficiency.

Two of the cases presented before have a "silver lining" of sorts, in that most public actors seem to be increasingly aware of this need to coordinate and articulate common solutions. Both in Charleston Slough and in the adoption of Ecotone Zones, "public v. public" conflicts never fully expressed themselves, but were rather on the verge of occurring, unless there was a negotiation or revision of standards and designs. Once frank discussion among all public actors was initiated, consensual solutions appeared easy to achieve.

4.4.2 Public vs. Private

The Redwood City Saltworks dispute is much less likely to have a straightforward and consensual solution, and the involvement of strong private stakes is at the heart of the dispute. One major element that is typically absent from public v. public disputes is the threat of litigation, especially from well-endowed developers or interest groups. While it may be seen as a somewhat minor problem in other constituencies, in the United States, and especially in California, the looming prospect of long and costly legal battles may lead to an overly cautious and conservative approach by public agencies (Fulton 2012: 92).

Public agencies have equally become somewhat disavowed in the transition from deterministic government to collaborative governance (Pincetl 2010). With limited resources and often lacking the clear legal mechanisms necessary to pursue their mandates, public agencies are left with the nearly-impossible task of fulfilling their public duty without the necessary means and power.

Wetland restoration actions have a very concrete spatial expression. As such, permitting and planning agencies need land for the restoration work, but the land use authority ultimately falls on local municipal governments. These governments are left sandwiched between powerful developers' motivations, the local government's own interest in economic development and (especially in the Bay's red-hot real-estate market) meet housing demand, and the restoration objectives.

Also, some of the vested interests of public agencies are not necessarily easy to quantify: "Because ecosystem services are not fully 'captured' in commercial markets or adequately quantified in terms comparable with economic services and manufactured capital, they are often given too little weight in policy decisions." (Costanza 1997), although that is not as clear-cut when flood control is an integral part of the restoration plan. The public benefits of these long-term plans, though, will tend to be protacted for several decades.

In contrast, the potential economic gains some private parties may derive from land use decisions may be quite extraordinary and easy to quantify. Luken (1974) assessed that the process of transforming SF Bay's wetlands onto "fastlands" (developed landfill) could equate to as much as a 75-fold increase in land value. It should be pointed out that some of these wetland tracts around the SF Bay were purchased in auction for as little as $1 per acre (i.e., $2.50/ha). Besides, it may yeld short-term benefits within a few years, and align more clearly with near-sighted political objectives. The likely escalation of costs in the maintenance and reinforcement of flood protection and infrastructure with SLR is too often left unmentioned, although it is a growing concern around the region (Stark 2015).

Looking more closely at the Saltworks example, even if that property was to be valued at the presumably inflated average value for all of the SBSPRP ponds – which stood at around $6,600/acre – that would still be about 34 times less than the $225,000/acre valuation for the Saltworks plot that was cited (and much-criticized) by Judge Benjamin (Fisher 2007). Simply put, assuming the Saltworks, or some areas therein, may be converted to real-estate, rather than reverted back to wetlands, could exponentially increase its value. It is no wonder, then, that the owner and the developer would be willing to fight prolonged and expensive legal battles to establish even partial building rights over an otherwise "worthless" property.

The conversion of tidal wetlands into fastlands, while being at odds with the principles of the Public Trust Doctrine, was determined not to be subject to reversion (Briscoe 1979, City of Berkeley v. Superior Court 1980). That applied to already developed landfill, though, under the principle of *fait accompli*.

Salt ponds are different. They were never fully developed, and remained subject to regular inundation by Waters of the US. Also, unlike most fastlands, no development rights over these ponds were ever legally recognized in the past. Whether they should be considered as part of the Public Trust or not is still a matter of controversy, as is indicated by USACE's decision for the Redwood City Saltworks. The relevance of the final decision, which falls now in the hands of the EPA, is that it will not only decide the fate of those particular salt ponds, but equally establish legal precedent for similar cases, around the Bay and indeed across the Country.

In other constituencies, legislation is frequently revised and expanded to address an evolving public agenda; in the United States, however, the protection of natural resources, especially from the 60s onwards, has often been achieved with recourse to bold interpretations of old statutes, including what some have characterized as a very liberal interpretation of narrow original mandates (Lazarus 1985). While this has worked for the past few decades, it also renders the whole logic of environmental protection vulnerable to challenges such as that posed by the Saltworks project.

Whether former wetlands are to be restored or not should be an explicit public policy, and not the object of semantic debates over the letter of the law. As private stakeholders become aware of some fragility in the original legal interpretations that have set the modern standards and doctrines, litigation on jurisdictional or zoning decisions has reached the point where a few agencies now take every possible precaution in avoiding it.

The National office of the USACE presented well-grounded arguments on why it would not declare the Saltworks jurisdictional under the RHA and the CWA. Yet, its interpretation is extremely cautious: at all steps of memorandum justifying its decision (USACE 2015), one can infer how preoccupied USACE was with the possibility of taking a stance that would render them in a position where they might be challenged in court, and establishing precedents that would affect other areas (they specifically mention New Orleans in their memorandum). The regional EPA office likely has very different concerns, namely that of opening up other disputed Bay shorelines to development in ponds behind levees if they are to be exempted from jurisdiction under the CWA.

4.4.3 Private vs. Private: for-profit vs. non-profit

Litigation and liability are a necessary element in sustaining a balance between the public, or common, interests, and the preservation of private rights. Abuse of this legitimate legal recourse, on the other hand, often conducts to situations where the public agencies or governments may become fearful of entering in disputes with well-endowed private parties and be forced into long, trying, and expensive legal battles.

While several public agencies have very limited resources (human or otherwise) to dedicate to long legal battles, and are therefore in a fragile situation when faced with litigation from wealthy private developers, corporations or interest groups, the balance is somewhat restored through the strong support from environmental NGOs, especially in more liberal constituencies such as the Bay. Well-established, and respected, NGOs such as Save The Bay, the Sierra Club, or the Audubon Society, among several others, have been extremely vocal in environmental advocacy, and have often actively opposed development of salt ponds or landfill around the Bay (Walker 2009). They also have a role in keeping the pressure on legislators and regulators to enforce environmental protection standards.

Both developers and environmental NGOs are able to resort to tools often not at the disposal of public agencies, such as extensive public outreach through mass mails, political lobbying, or the creation of media campaigns. While in other parts of the country the balance may have tipped well to the side of private development interests, in the Bay these legal battles have often been decided in favor of habitat protection and restoration, and public agencies active in the region will likely take comfort in having a lot of public support for their activity.

4.5 Conclusions

While broad mitigation/adaptation strategies are decided at the National or State levels, the actual implementation of SLR adaptation measures often require a great deal of involvement of local actors. Given that it is at this juncture that adaptation takes a concrete spatial expression, this is also the moment when land-use conflicts arise. Local governments are left with much of the burden of mediating competing interests, between urban development, environmental protection, and other social demands. In some instances, the prospect of shoreline development may be very attractive for both property owners/developers and local governments, given the potential land value and economic benefits, but these have to be weighed against the medium-/long-term costs of defending these assets from rising sea-levels.

In San Francisco Bay, there is an increasing awareness of the challenges posed by SLR, but the institutional arrangements are complex, and communication between the different public agencies/departments is not always as streamlined as it could be. Some agencies and departments need to adapt their procedures in order to remove institutional barriers to adaptation, but path dependence is an obstacle. The several projects where different federal and state agencies are partnered with local governments highlight the benefits of a more frank and regular communication between public actors. It also emphasizes the benefits of a coordination of efforts and strategies, something that was eroded in the transition from government-led policies to a new paradigm of local-based adaptive governance.

While the articulation of public actors is often easy to address by increasing communication and coordination, conflicts involving private landowners and developers may be much complicated by the threat of litigation. The lack of a strong legal backing to public environmental protection mandates is a major obstacle to shoreline planning around the Bay and elsewhere, and this is highlighted by the extreme caution of some public agencies in upholding their jurisdictions over private property.

Environmental NGOs have, in the case of California, a big role to play, as they are able to resort to the same legal and lobbying instruments as the developers, and may help even-out the field between public stakeholders with limited legal and economic resources, and powerful private developers with nothing to lose. There is seemingly a sense of urgency in pushing for the development of shorefront properties, as public opposition to development on locations exposed to SLR is most likely to increase in the coming decades. At the same time, NGOs and public agencies are aware of the stress wetlands will be under as the rates of SLR increase towards the end of the century.

“Green”, or ecosystem-based, adaptation is already on the way around the Bay. Large scale wetland restoration projects have already been concluded, and further action now often requires articulation with the reinforcement of flood defense structures, given the level of urban encroachment. While levee setback, or removal, would provide greater environmental benefit, the need to protect urban areas and infrastructure has led to the trial of ingenious solutions for promoting wetland resilience while upgrading the level of protection granted by levees.

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APPENDIX A – SEA-LEVEL RISE MAPPING FOR THE SAN FRANCISCO BAY

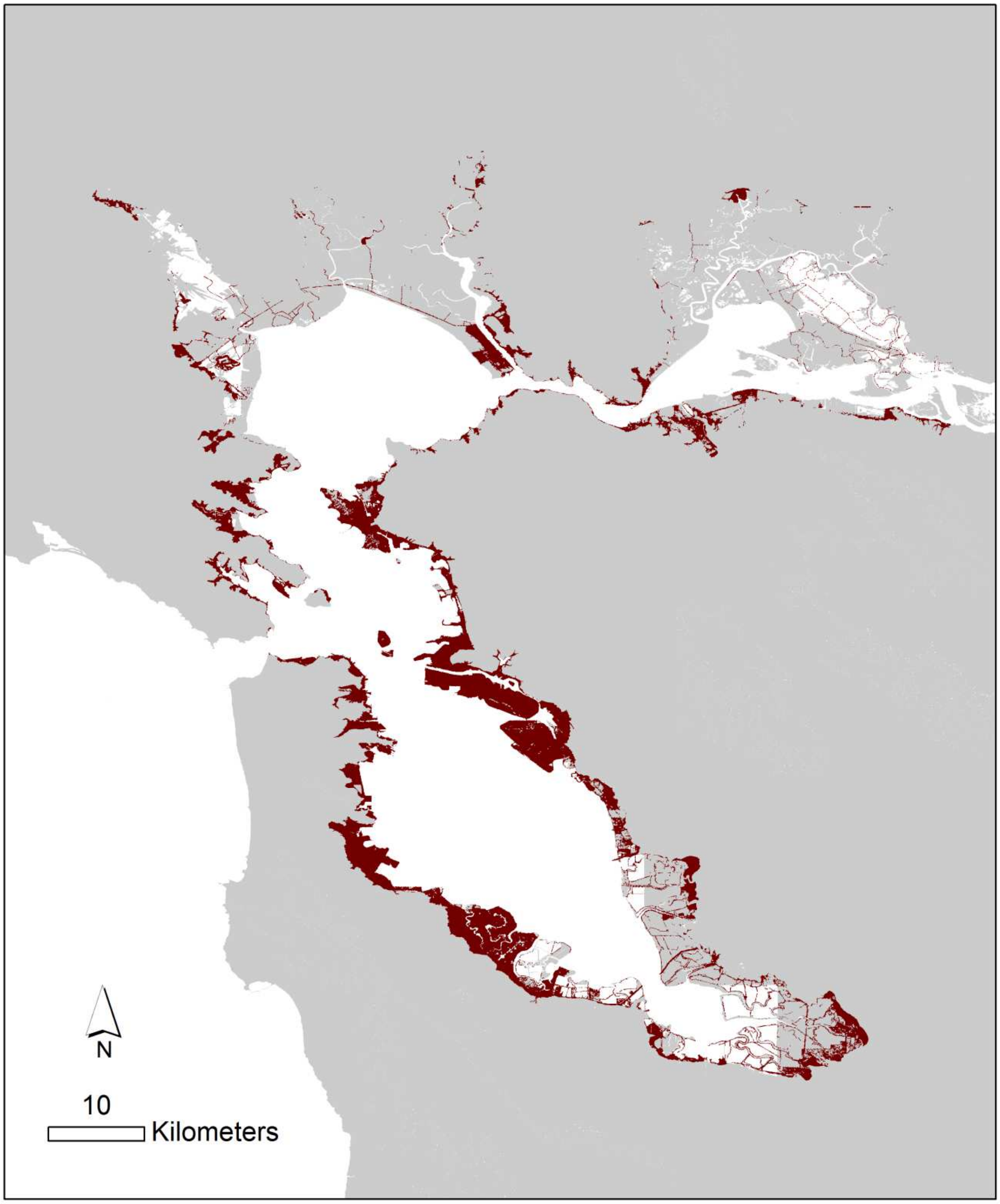

Figure A. 1 – Current situation at ~0 m (MSL) (Brown: urban development over former wetlands)

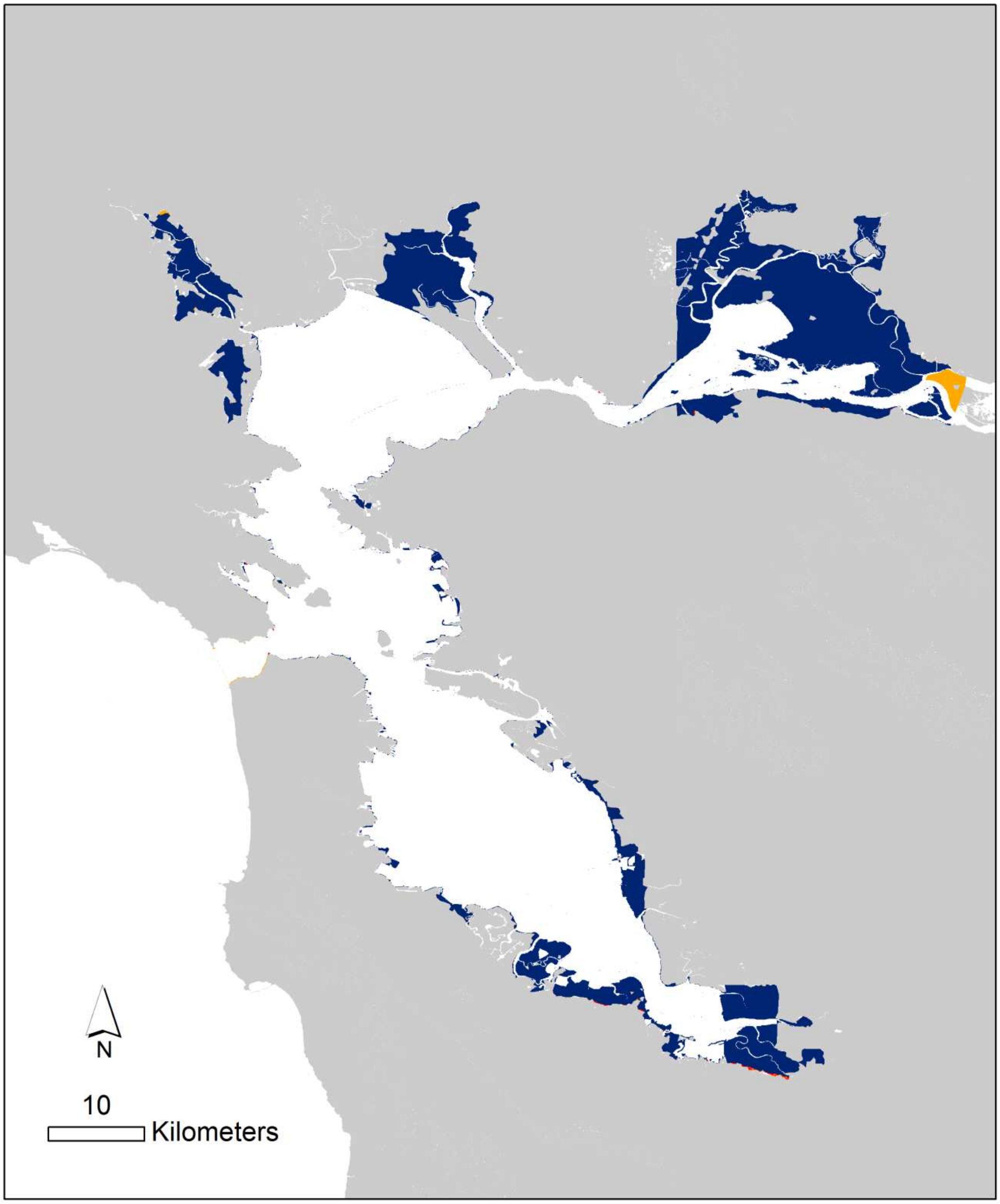

Figure A. 2 – +1 m above current MSL (Blue: Wetlands below water level; Red: Artificial (urban) areas below water level; Yellow: Non-artificial areas below water level)

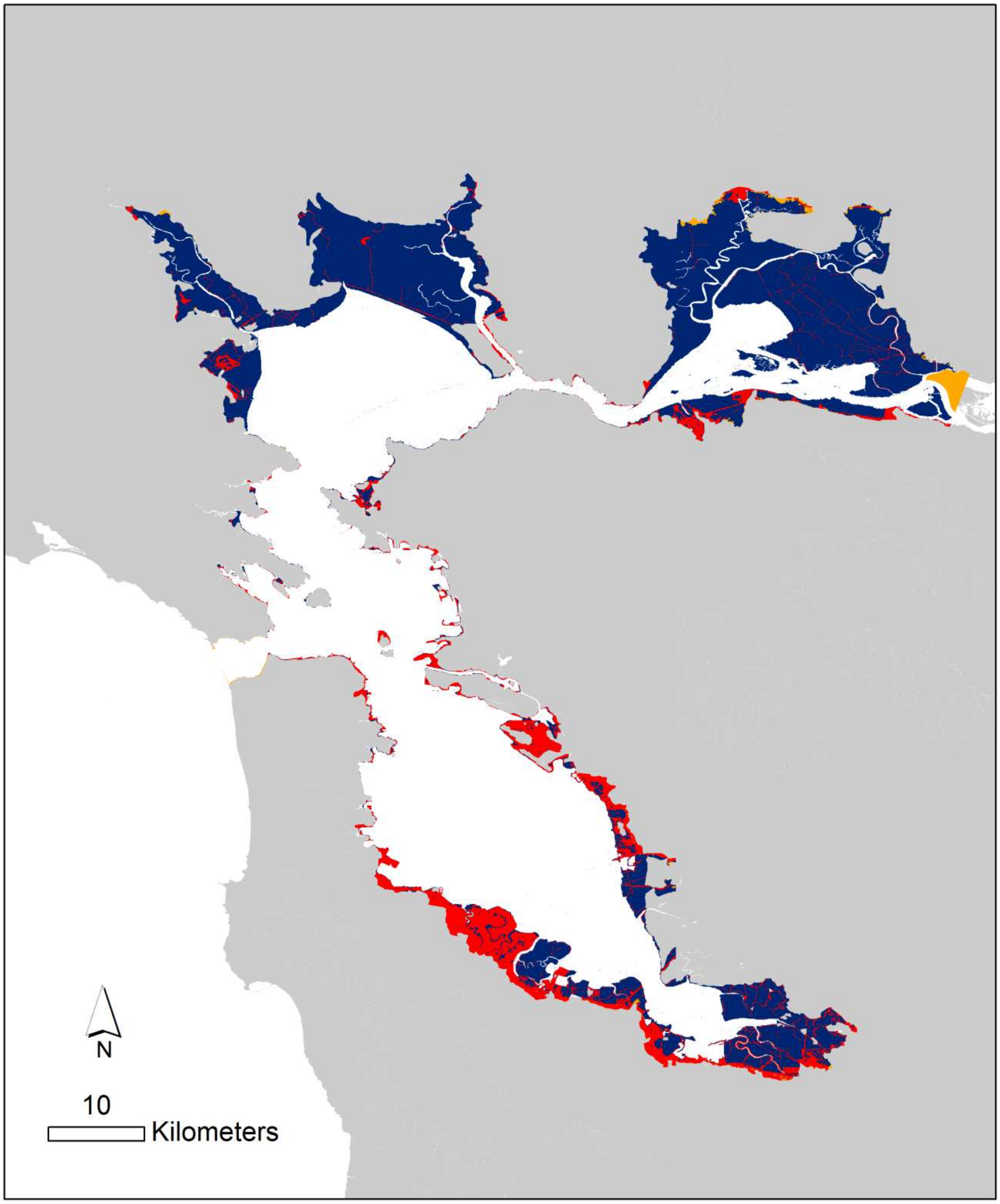

Figure A. 3 – +2 m above current MSL (Blue: Wetlands below water level; Red: Artificial (urban) areas below water level; Yellow: Non-artificial areas below water level)

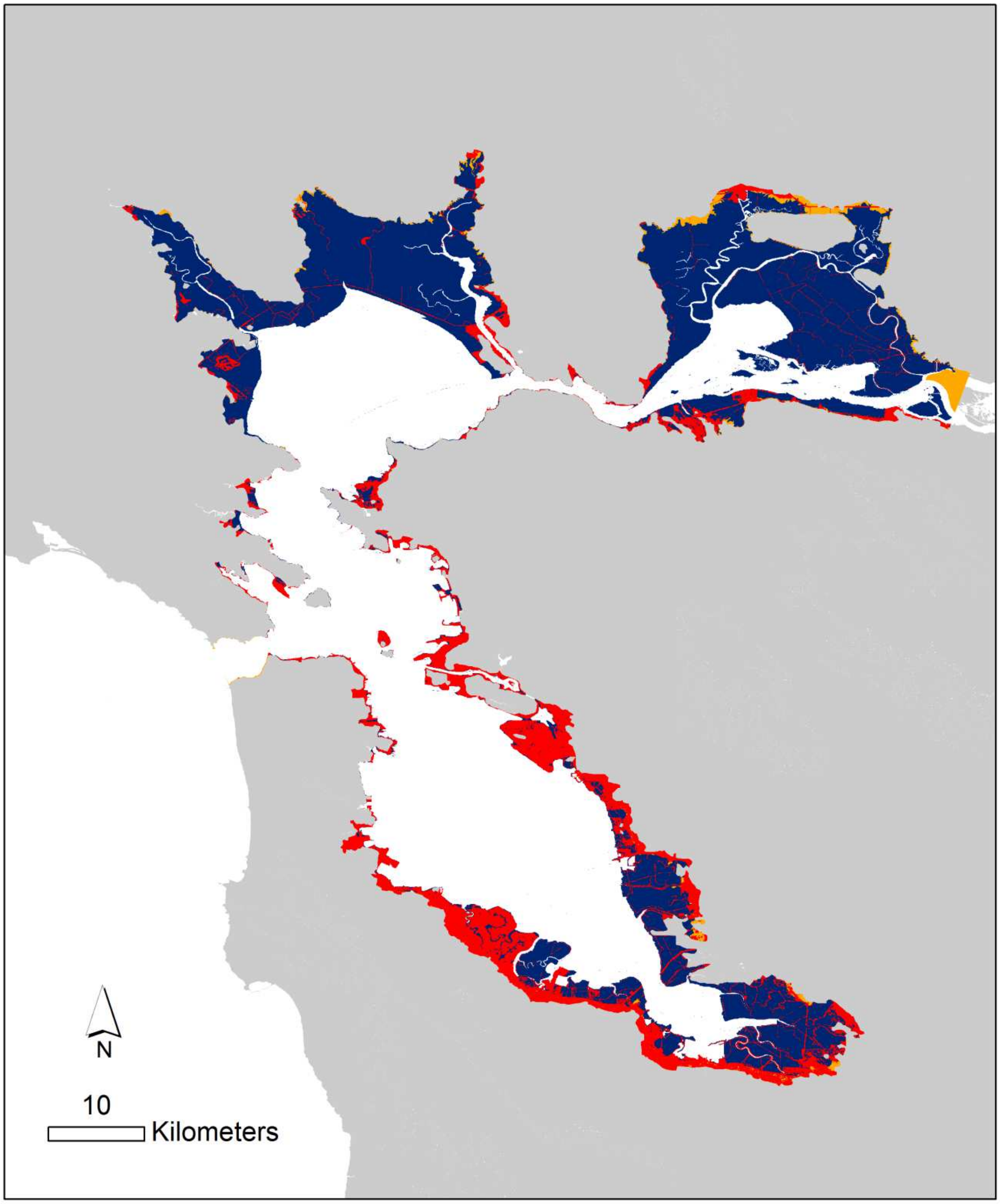

Figure A. 4 – +3 m above current MSL (Blue: Wetlands below water level; Red: Artificial (urban) areas below water level; Yellow: Non-artificial areas below water level)

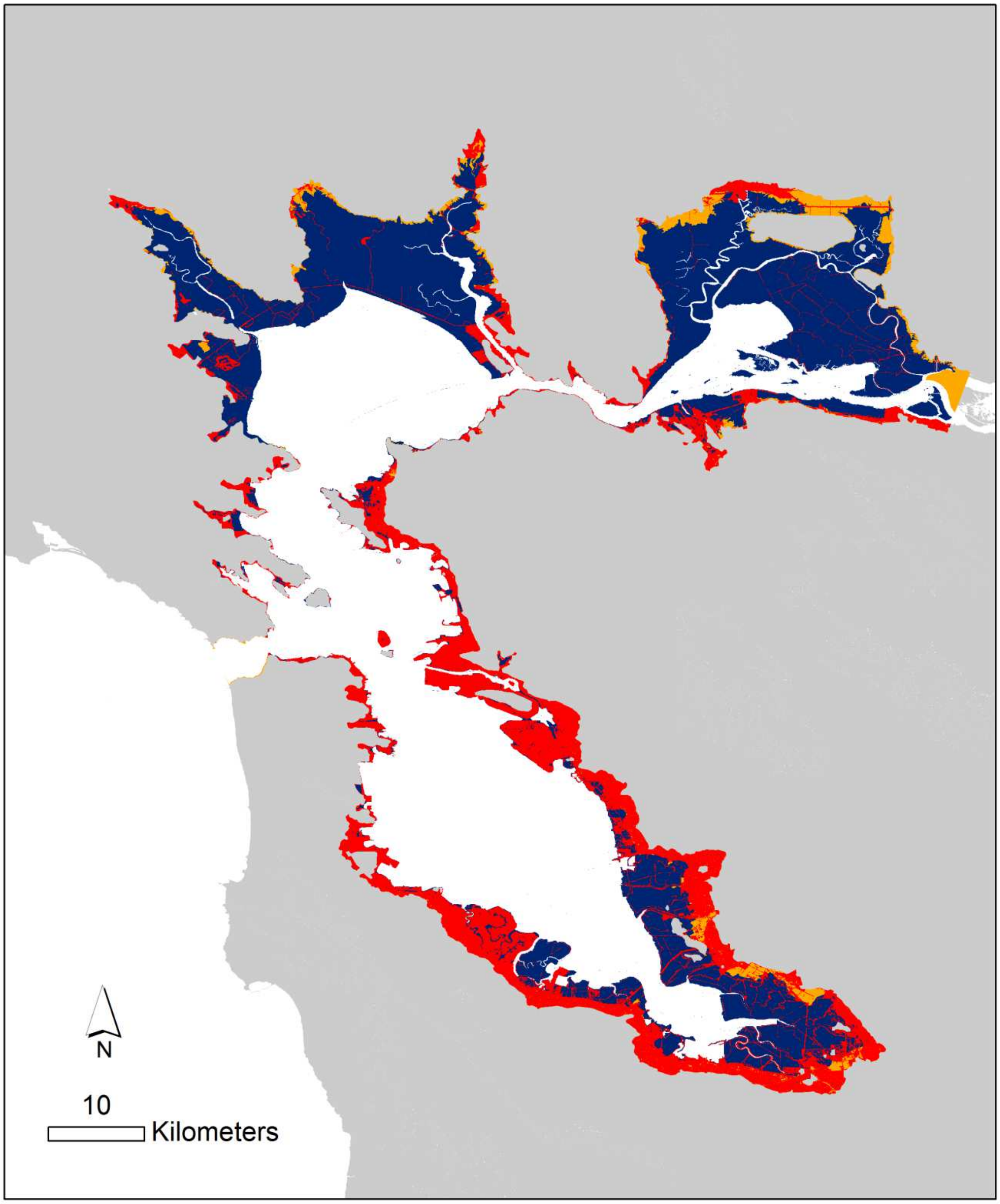

Figure A. 5 – +5 m above current MSL (Blue: Wetlands below water level; Red: Artificial (urban) areas below water level; Yellow: Non-artificial areas below water level)

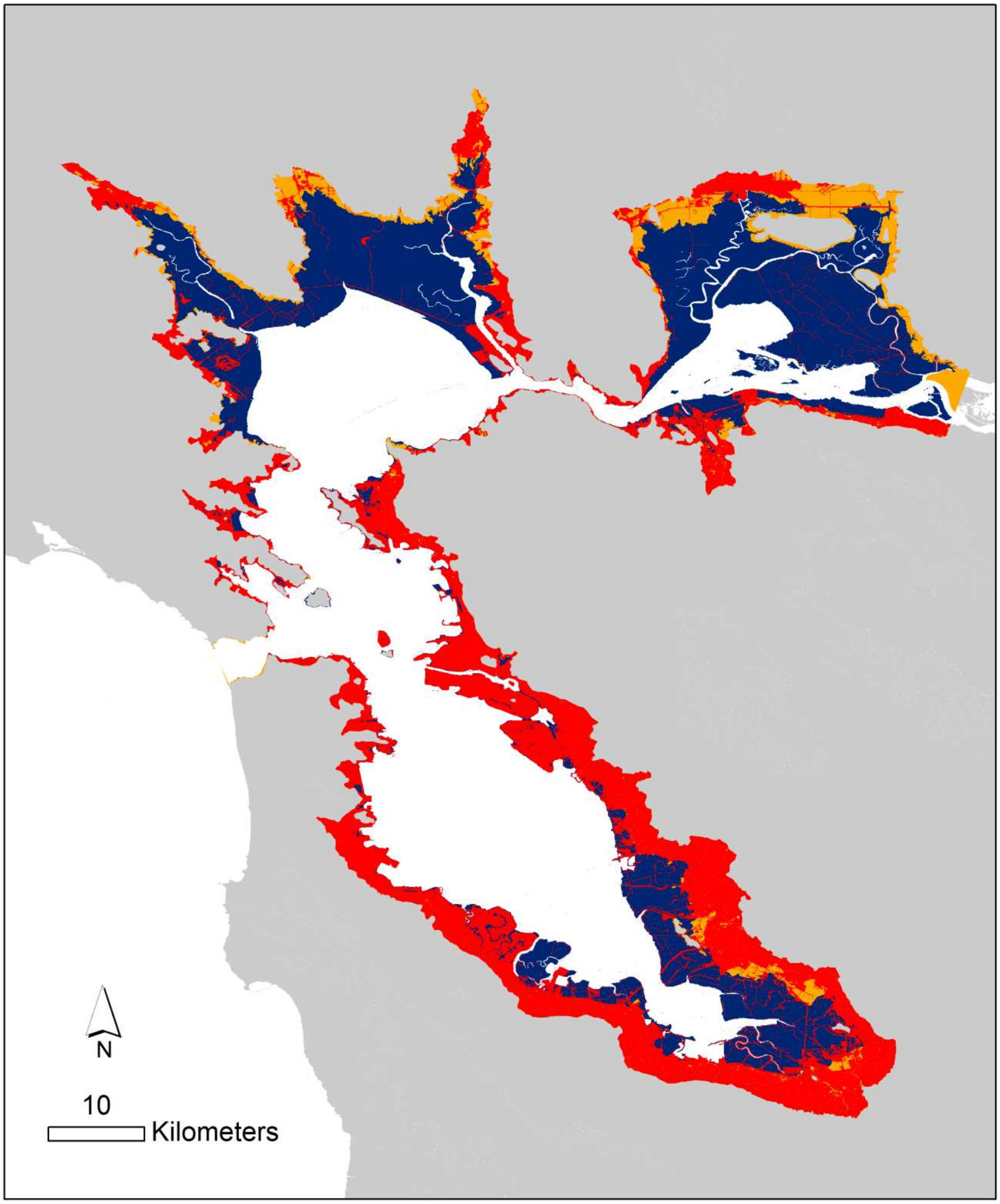

Figure A. 6 – +10 m above current MSL (Blue: Wetlands below water level; Red: Artificial (urban) areas below water level; Yellow: Non-artificial areas below water level)

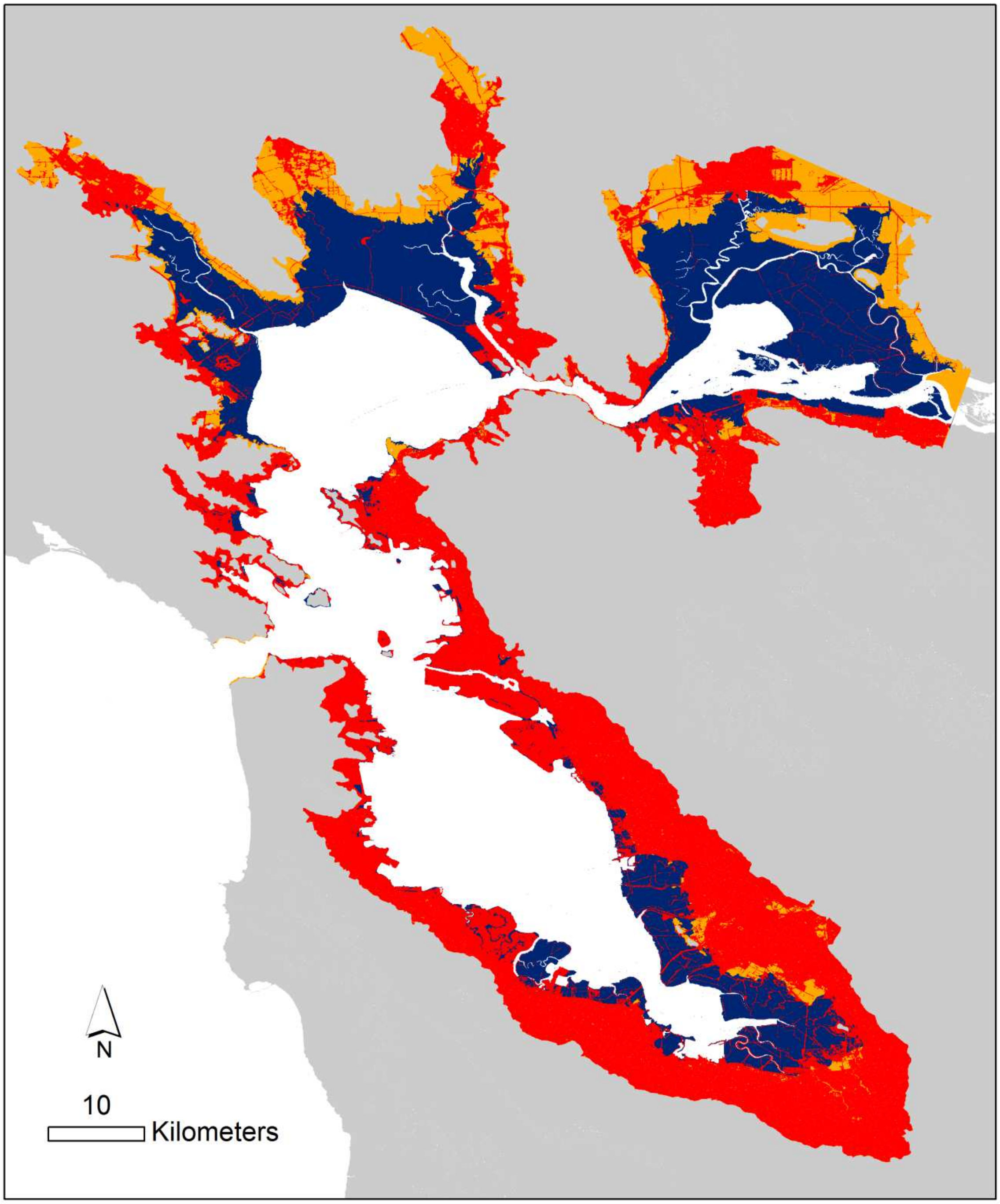

Figure A. 7 – +25 m above current MSL (Blue: Wetlands below water level; Red: Artificial (urban) areas below water level; Yellow: Non-artificial areas below water level)

APPENDIX B – SEA-LEVEL RISE MAPPING FOR THE TAGUS ESTUARY

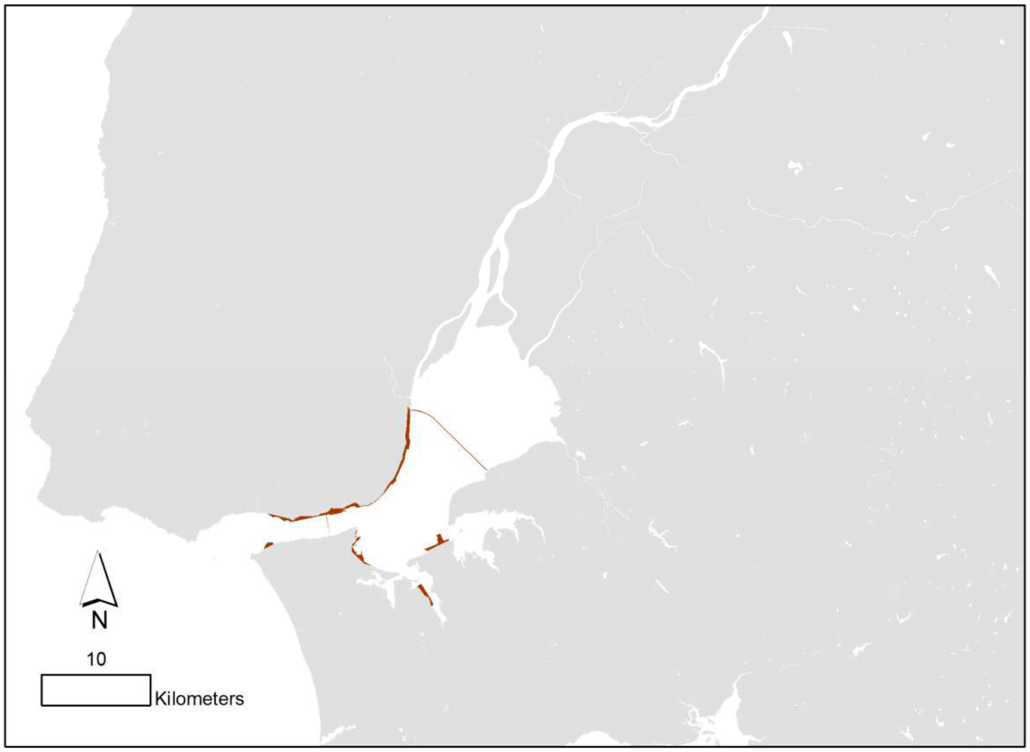

Figure B. 1 – Current situation at ~0 m (MSL) (Brown: urban development over former wetlands).

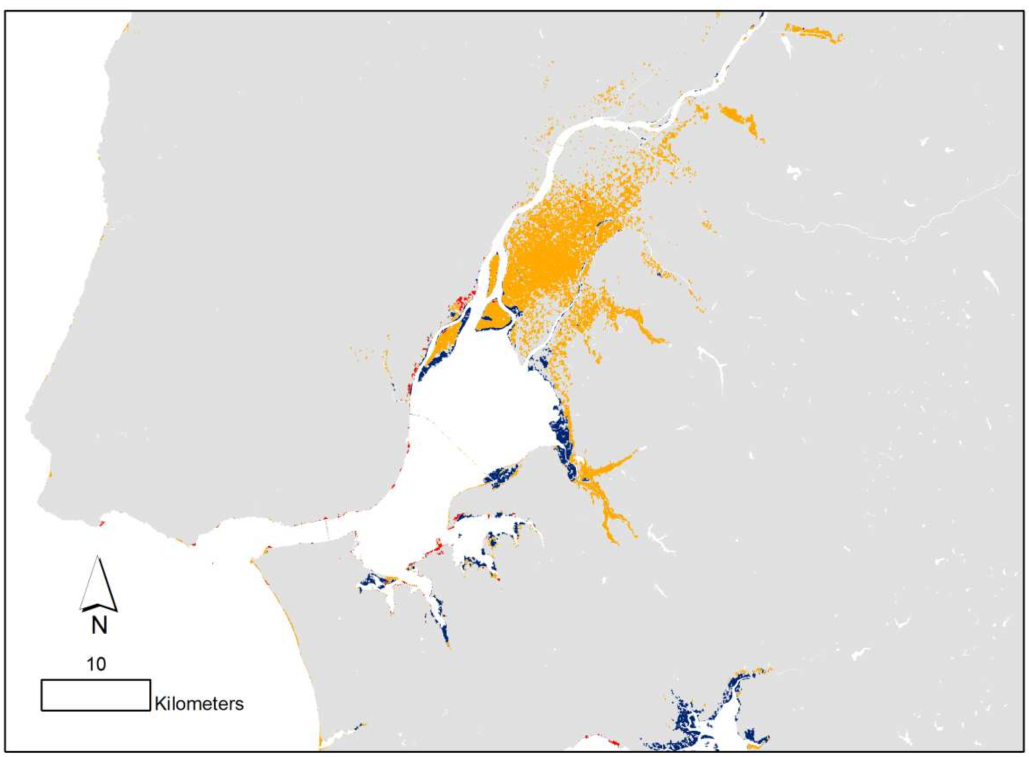

Figure B. 2 – +1 m above current MSL (Blue: Wetlands below water level; Red: Artificial areas below water level; Yellow: Non-artificial areas below water level)

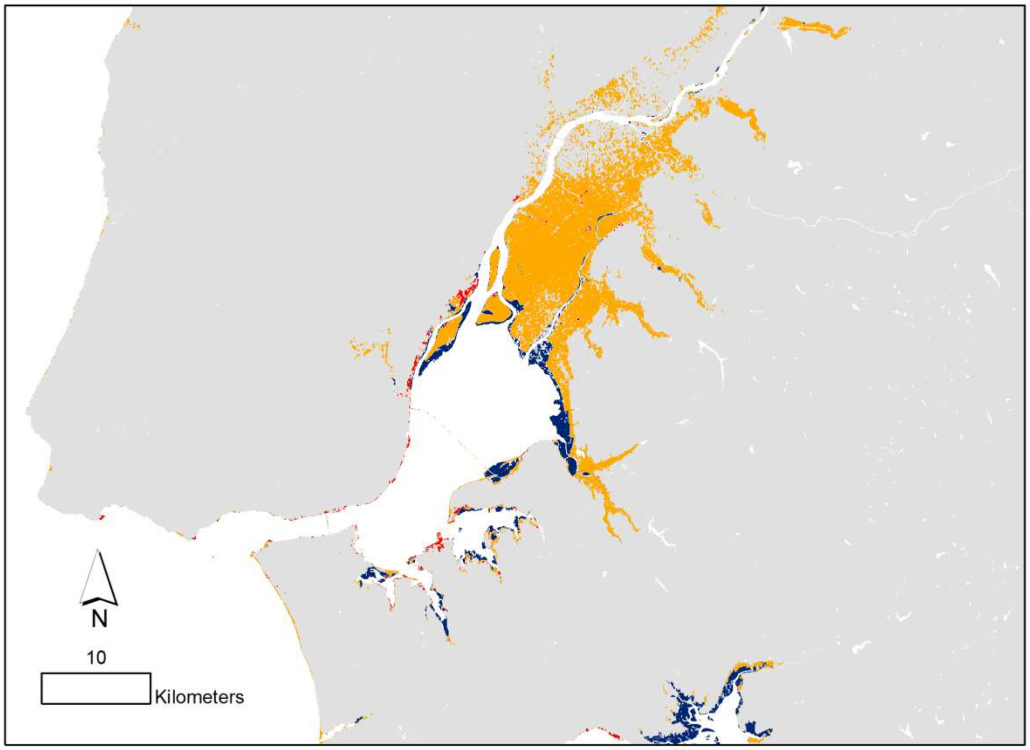

Figure B. 3 – +2 m above current MSL (Blue: Wetlands below water level; Red: Artificial areas below water level; Yellow: Non-artificial areas below water level)

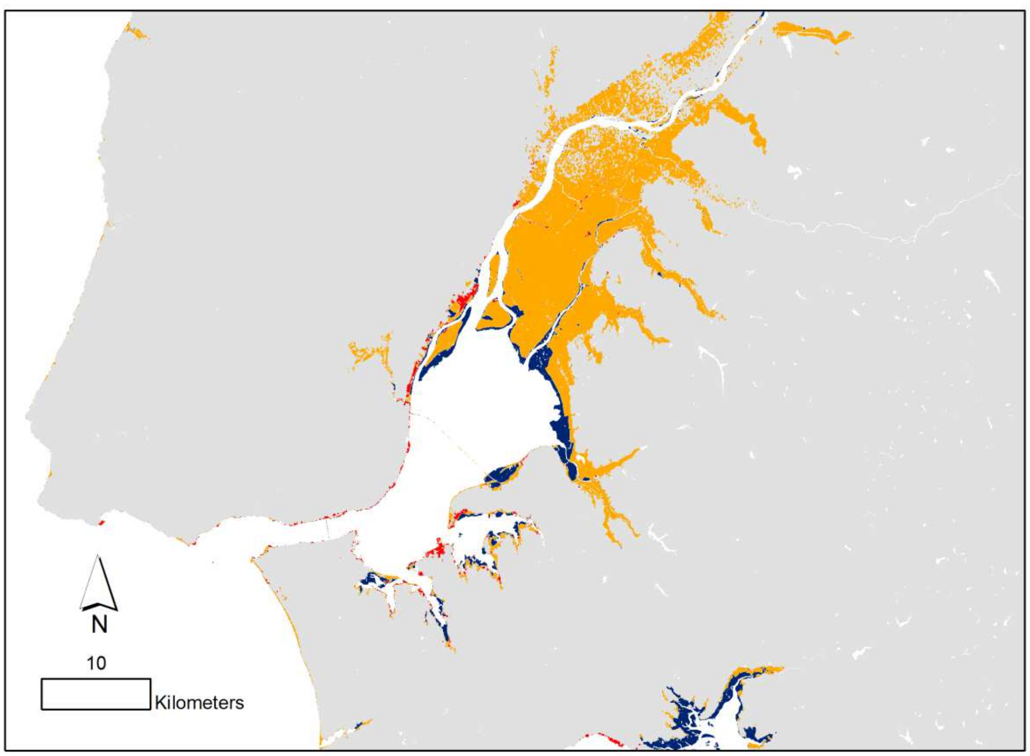

Figure B. 4 – +3 m above current MSL (Blue: Wetlands below water level; Red: Artificial areas below water level; Yellow: Non-artificial areas below water level)

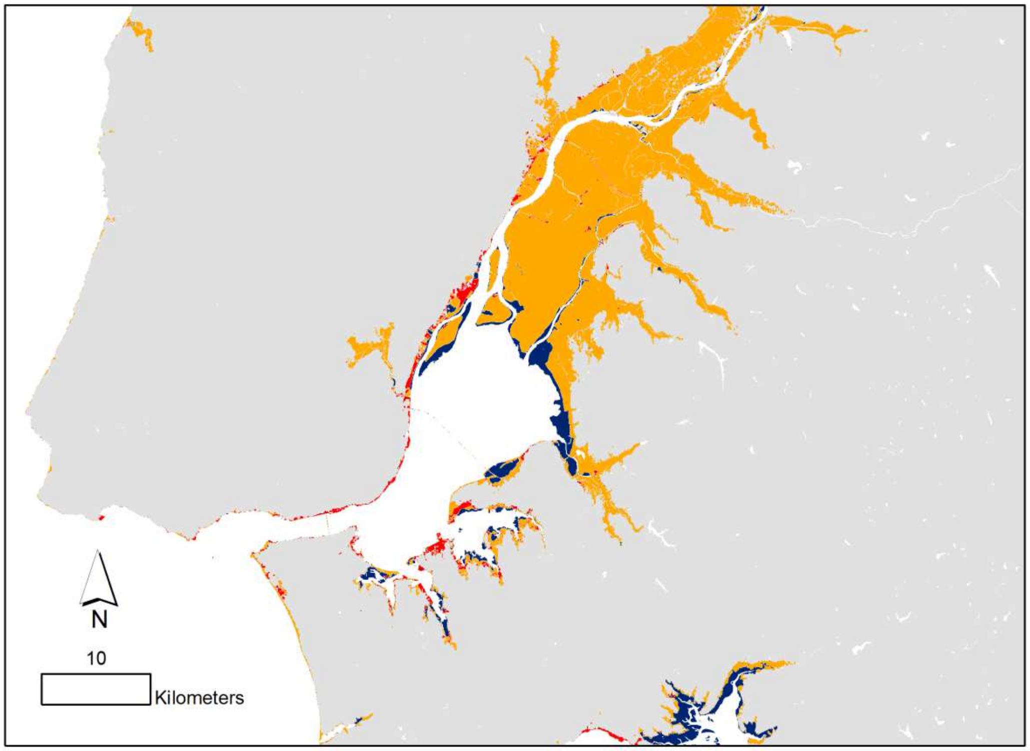

Figure B. 5 – +5 m above current MSL (Blue: Wetlands below water level; Red: Artificial areas below water level; Yellow: Non-artificial areas below water level)

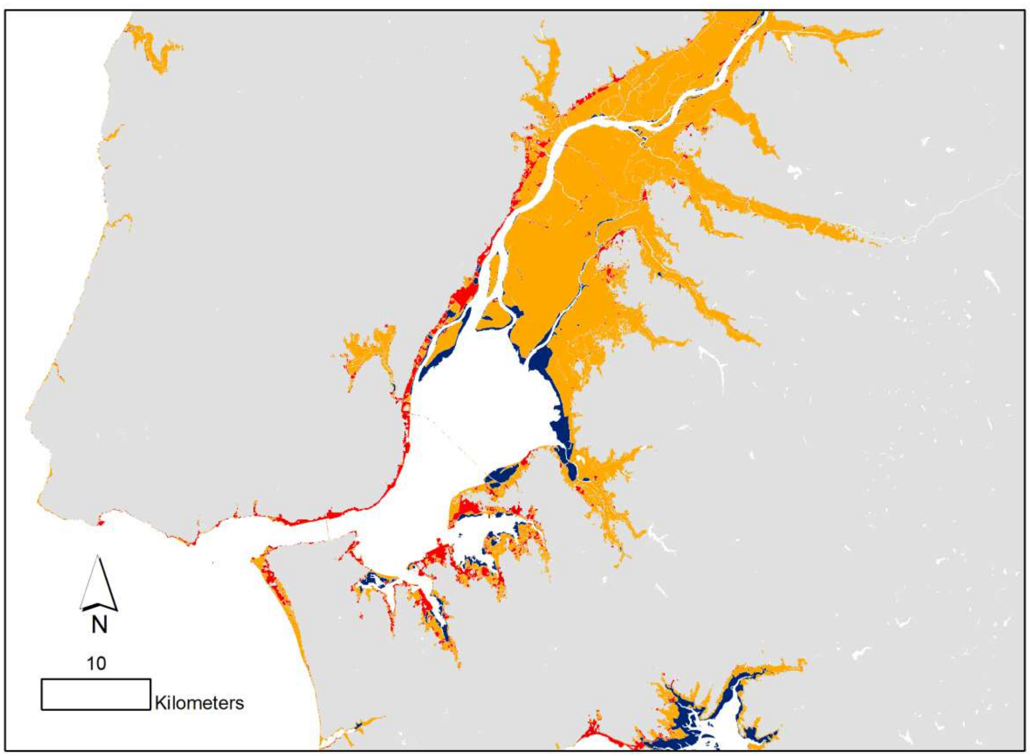

Figure B. 6 – +10 m above current MSL (Blue: Wetlands below water level; Red: Artificial areas below water level; Yellow: Non-artificial areas below water level)

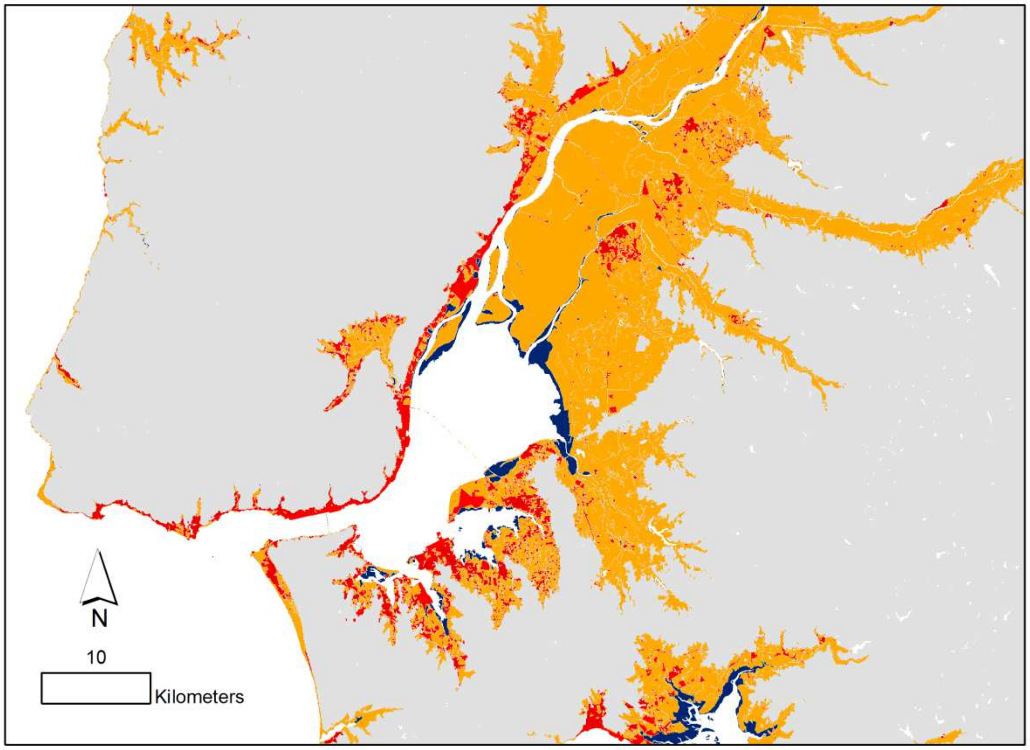

Figure B. 7 – +25 m above current MSL (Blue: Wetlands below water level; Red: Artificial areas below water level; Yellow: Non-artificial areas below water level)

APPENDIX C – COMPARISON OF AREAS RENDERED BELOW SLR IN SAN FRANCISCO BAY AND TAGUS ESTUARY

Land Use Class	San Francisco Bay - Elevation above current Mean Sea Level (m)								
	0	1	2	3	5	10	15	20	25
Urban Fabric	0	88	1.354	4.174	13.630	37.062	56.664	71.740	83.923
Other artificial areas	173	1.632	6.772	10.821	15.069	18.193	18.537	18.628	18.684
Farmed or grazed land	0	2.816	9.952	12.499	13.706	15.213	16.747	18.508	20.428
Forest	0	3	5	10	51	106	199	293	434
Grass, shrub or scrub	0	18	348	1.487	4.107	8.474	12.152	14.790	17.354
Barren land	94	859	2.398	3.514	4.056	4.538	4.648	4.709	4.809
Salt and regulated ponds	*760*	*11.986*	*17.161*	*21.550*	*23.584*	*23.851*	*23.862*	*23.866*	*23.868*
Natural wetlands	*1.440*	*25.353*	*32.999*	*35.154*	*35.947*	*36.376*	*36.474*	*36.554*	*36.576*
Wetlands (marshes)	2.200	37.339	50.160	56.704	59.531	60.228	60.336	60.420	60.445
Wetlands (mudflats)	9.771	11.200	11.582	11.698	11.755	11.793	11.796	11.796	11.797
Total under sea-level	14.439	91.293	132.730	157.611	181.436	215.835	241.415	261.303	278.319
Permanently flooded	101.775	102.319	103.022	103.229	103.685	103.767	103.979	104.060	104.089

Table C. 1 – Land area of each classof land use rendered below each step of SLR above current MSL (in hectares) – San Francisco Bay

Land Use Class	Tagus Estuary - Elevation above current Mean Sea Level (m)								
	0	1	2	3	5	10	15	20	25
Urban Fabric	0	166	555	881	1.745	4.436	7.525	10.321	12.608
Other artificial areas	0	31	120	178	266	578	949	1.284	1.550
Farmed or grazed land	0	4.991	19.804	27.453	37.813	51.846	68.906	82.523	93.974
Forest	0	5	123	326	919	2.996	6.117	10.379	15.455
Grass, shrub or scrub	0	53	494	892	1.730	3.628	5.930	8.636	11.627
Barren land	0	84	183	213	266	541	902	1.090	1.232
Wetlands (marshes)	0	1.194	3.289	3.784	3.997	4.109	4.340	4.439	4.455
Wetlands (mudflats)	15.280	15.280	15.280	15.280	15.280	15.280	15.280	15.280	15.280
Total under sea-level	15.280	21.805	39.848	49.006	62.016	83.413	109.949	133.952	156.182
Permanently flooded	29.792	29.792	31.460	31.782	32.374	32.963	33.778	34.232	34.526

Table C. 2 – Land area of each classof land use rendered below each step of SLR above current MSL (in hectares) – Tagus Estuary