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PARK Science

Integrating Research and Resource Management in the National Parks

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SALT-MARSH MAKEOVER AT GATEWAY

A multiagency program restores marsh islands in Jamaica Bay, but can the causes of marsh loss be reveresed in this urban estuary?

ON THE COVER

Low tide in Jamaica Bay, New York, reveals Elders Point was once a single marsh island; however, most of what was once emergent salt marsh is now subtidal and intertidal mudflat. In this October 2009 image, the light pink color and dark red swirls on the mudflat are caused by *Ulva* (sea lettuce), a green alga that is prevalent in the nutrient-rich waters of Jamaica Bay. Restoration of 15.8 hectares (39 ac) of salt marsh at Elders Point East (island at top center) was conducted in 2006–2007. Elders Point West (see page 4, left photo, at left), prior to restoration, consists of a small area of upland and a band of *Spartina alterniflora*. For more information see the article on page 34.

U.S. ARMY CORPS OF ENGINEERS

Restoration Journal

Building partnerships to restore an urban marsh ecosystem at Gateway National Recreation Area

GALVIN BROTHERS, INC.

Elders East, Gateway National Recreation Area

By Patricia Rafferty, JoAnne Castagna, and Doug Adamo

THE JAMAICA BAY ESTUARY IS LOcated on the western end of Long Island, New York (fig. 1), and most of the bay is part of the Jamaica Bay Unit of Gateway National Recreation Area. Historically the bay was known for an abundance and diversity of shellfish. In addition, with extensive marsh islands, tidal creeks, mudflats, and brackish water, the bay has served as an important nursery and feeding ground for many species of birds and fish. However, over time the Jamaica Bay ecosystem has been altered. Urban development has caused widespread changes in the quantity and quality of bay waters and much of the bay shoreline has been hardened and modified. The natural flow of water and sediment into the bay has been affected by channel dredging, stormwater runoff diversion, sewage treatment plant operations, and causeway construction. In addition, the Rockaway Inlet, on the bay's southern shore, has migrated to the west over many years and has constricted flow into the bay. The bay also has experienced the conversion of more than 60% of the vegetated salt-marsh islands to intertidal and subtidal mudflats. Between 1951 and 2008, 647.5 hectares (1,600 ac) of salt marsh were lost; the current rate of loss is 7.7 hectares (19 ac) per year.

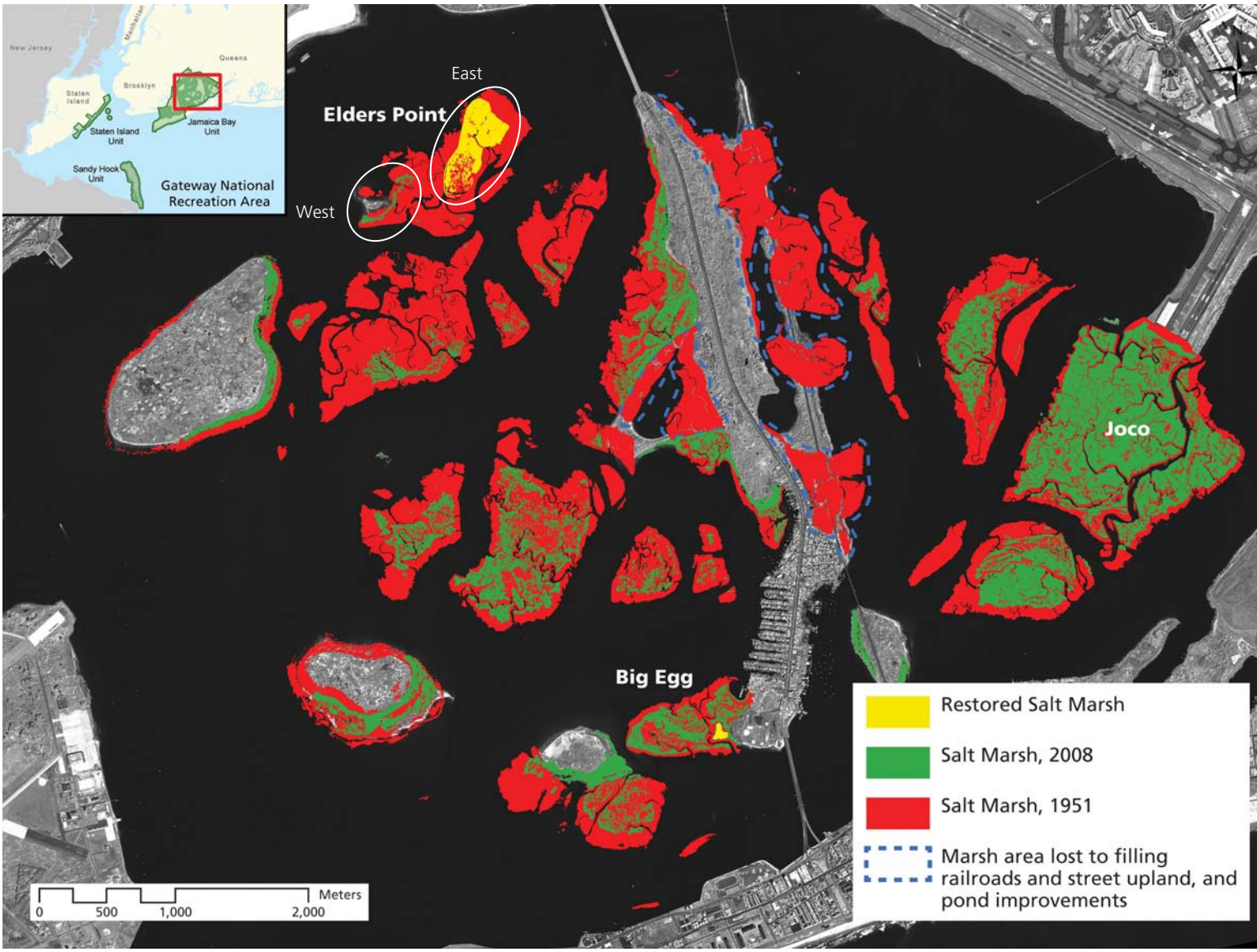

Figure 1. Change in salt-marsh islands in Jamaica Bay, New York, from 1951 to 2008. Change analysis is based upon heads-up digitizing of 1951 aerial photographs (minimum mapping unit = 20 sq m or 23.9 sq yd) and unsupervised classification of 2008 QuickBird satellite imagery (minimum mapping unit approximately 2 sq m (2.4 sq yd). Big Egg and Elders Point East marsh restorations, as well as the JoCo control marsh, are labeled. Elders Point West restoration (constructed in 2010) is not depicted in this analysis.

CHANGE ANALYSIS: M. CHRISTIANO AND K. MELLANDER , GATEWAY NATIONAL RECREATION AREA; FIGURE COURTESY OF M. CHRISTIANO, GATEWAY NATIONAL RECREATION AREA

Causes of marsh loss in Jamaica Bay

Understanding, managing, and reversing the causes of marsh loss are key to the long-term success of restoration efforts in Jamaica Bay. The National Park Service has worked with university and federal partners to identify and understand the causes of marsh loss in this urban estuary.

Increases in the frequency and duration of marsh flooding due to anthropogenic changes in tidal range have likely contributed to the loss of vegetated salt-marsh islands within Jamaica Bay (Swanson and Wilson 2008). Channel dredging, completed in the first half of the 20th century, increased the volume of the bay by 350% (NYCDEP 2007) and the mean depth from approximately 1 to 5 meters (3.3–16.4 ft) (Swanson et al. 1992). Historical increases in tidal range have resulted in high-tide water levels today that are 56–78% greater than increases due to sea level rise (Swanson and Wilson 2008).

Working with partners has been key to advancing our understanding of marsh loss in Jamaica Bay as well as implementing marsh restoration and monitoring.

In addition, sediment is trapped in deep pits that were excavated in the bay bottom to provide fill for development in the bay's fringing wetlands. Hydrodynamic modeling indicates that there is little deposition of sediment within dredged navigation channels; however, deep pits, such as Grassy Bay, may serve as sinks for fine sediments (Wilson and Flagg 2008) that could otherwise be transported to the marsh surface. Inorganic sediments are moved by tides through the inlet and deposited in the western bay. During storm events, sediments are subsequently transported to the eastern portion of the bay, including Grassy Bay (Renfro et al. 2010).

Sediment supply to marshes may be insufficient to maintain marsh elevation. Marsh elevation is controlled by the deposition or removal of sediment from the surface of the marsh and subsurface processes such as peat accumulation, decomposition, pore-water storage, and subsidence. The inorganic mass of marsh sediments has decreased in Jamaica Bay marshes since European settlement (Peteet et al. 2008) while organic matter has increased over the same period (Peteet et al. 2004). Despite this historical decrease in inorganic sediment availability, long- (over the past 100 years) (Kolker 2005) and short-term (since 2003) (U.S. Geological Survey, Patuxent Wildlife Research Center, D. Cahoon, research ecologist, personal communication, 22 October 2008) marsh surface sediment accumulation rates in Jamaica Bay exceed the rate of long-term regional sea level rise at the Battery, New York (0.28 centimeters or 0.11 inches per year); however, recent rates of sediment accumulation in some marshes are not sufficient to maintain marsh elevation given the combined rates of shallow subsidence and regional sea level rise (U.S. Geological Survey, Patuxent Wildlife Research Center, D. Cahoon, research ecologist, personal communication, 1 December 2010). Many of the marsh islands are submerging or getting wetter.

High nutrient levels in the bay may increase the rate of shallow subsidence. Jamaica Bay is frequently referred to as having a "sewershed" since the primary source of freshwater is four New York City Water Pollution Control facilities and numerous combined sewer overflow pipes. Nitrogen loading in Jamaica Bay has increased by more than 400% in the past 110 years from an estimated 35.6 kilograms (78 lb) of nitrogen per day, which entered the bay via submarine groundwater discharge, to 15,785 kilograms (34,800 lb) of nitrogen per day that enters the bay via wastewater discharge, subway dewatering, landfill leachate, submarine groundwater discharge, and atmospheric deposition (Benotti et al. 2007). Smooth cordgrass (*Spartina alterniflora*) is the dominant vegetation in salt marshes along the Atlantic and Gulf coasts of North America. High nutrient loading may decrease root production in *S. alterniflora* (Valiela et al. 1976; Morris and Bradley 1999; Turner et al. 2009) and/or increase the rate of peat decomposition (Valiela et al. 1985). *S. alterniflora* belowground biomass contributes to marsh elevation (Valiela et al. 1976; DeLaune et al. 1994; Morris and Bradley 1999) and its roots bind sediments and slow sediment compaction (Redfield 1972; DeLaune et al. 1994; Rybczyk and Cahoon 2002). The U.S. Environmental Protection Agency is conducting research to evaluate soil respiration, above- and belowground biomass, and root structure at numerous marshes in Jamaica Bay and across Long Island (Wigand et al. 2008). In 2009, the National Park Service initiated research to evaluate the role of nutrient enrichment (eutrophication) in the allocation of resources between above- and belowground biomass at three marshes in Jamaica Bay.

Fresh organic carbon from combined sewer overflows and algal blooms may also contribute to marsh loss by fueling sulfate reduction in marsh sediments and causing elevated pore-water sulfide concentrations. In greenhouse studies, prolonged exposure of *S. alterniflora* to moderate and high pore-water sulfides caused stunted growth and death, respectively (Koch and Mendelssohn 1989). Pore-water sulfide concentrations that are consid-

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Figure 2. Experimental salt-marsh restoration in Jamaica Bay has relied upon increasing elevation by the placement of clean sediment. At Big Egg, top, a swing-ladder dredge was used to spray sediment onto the marsh surface. At Elders Point East (page 34) and West, above at bottom, slurried sediments were pumped onto the restoration site and mechanically moved and graded.

ered stressful to *S. alterniflora* have been observed in Jamaica Bay marshes (Cochran et al. 2009).

Experimental marsh restoration

In response to the rapid loss of salt-marsh islands in Jamaica Bay, Gateway National Recreation Area embarked on an experimental restoration project at Big Egg Marsh. In September 2003, a self-propelled swing-ladder dredge (fig. 2) sprayed a layer of sand slurry on 0.8 hectare (2 ac) of severely degraded salt marsh to achieve an elevation suitable for the planting, growth, and survival of *S. alterniflora*. Monitoring of vegetation, benthos (benthic organisms), insects, birds, and sediment elevation was conducted at the restoration and control sites from 2003 to 2008 to evaluate the restoration. In addition, this experimental restoration site provided public access for volunteer participation in restoration planting and monitoring as well as education and outreach.

In 2006, construction of a much larger 15.8-hectare (39 ac) experimental salt-marsh restoration project was initiated at Elders Point East (fig. 2). This multiagency effort was led by the U.S. Army Corps of Engineers, New York District, and was the result of years of interagency collaboration, environmental planning, and engineering by the U.S. Army Corps of Engineers, Port Authority of New York and New Jersey (the nonfederal cost-share partner), New York State Department of Environmental Conservation, New York City Department of Environmental Protection, New York State Department of State, U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, and National Park Service. Restoration of Elders Point East was funded by and fulfilled mitigation requirements of the New York Harbor Deepening Project.

This multiagency team continues to work collaboratively toward restoration of the Jamaica Bay ecosystem, including salt-marsh island restoration. In 2010, building upon the lessons learned at Big Egg and Elders Point East, the team completed construction for the restoration of an additional 13.4 hectares (33.2 ac) of salt marsh at Elders Point West (fig. 2). The U.S. Army Corps of Engineers, New York City Department of Environmental Protection, and New York State Department of Environmental Conservation provided funding for the 2010 restoration and will also share in the cost of restoring three additional marsh islands in Jamaica Bay. Design plans and specifications for the three islands are under development, and construction is targeted for federal fiscal year 2012.

In addition to agency staff resources, these restoration projects represent a substantial financial commitment. Planning and construction costs ($315,536) for the Big Egg experimental restoration were funded by the National Park Service. The addition of in-kind contributions, including park staff time and volunteer participation, more than doubles the

The goal of the monitoring is to determine factors contributing to the success or failure of the restoration, test various Spartina *planting techniques, justify adaptive management actions, and better understand factors contributing to marsh loss throughout Jamaica Bay.*

cost of the project. U.S. Army Corps of Engineers and local cost-share partners have funded restoration at Elders Point East and West. Planning, design, and engineering costs for Elders East and West exceeded $3 million; however, planning, design, and engineering costs of subsequent projects are expected to be less than $400,000 per project. Construction costs at Elders East and West were $12,941,569 and $11,936,100, respectively.

Marsh restoration monitoring

This multiagency team has also developed and implemented a comprehensive monitoring and adaptive management program for the restoration of Elders Point East and West. The monitoring program was based in part on experiences from the Big Egg marsh restoration. The goal of monitoring is to determine factors contributing to the success or failure of the restoration, test various *Spartina* planting techniques, justify adaptive management actions, and better understand factors contributing to marsh loss throughout Jamaica Bay. Monitoring of vegetation, nekton, birds, benthos, sediment elevation, habitat, and landscape parameters at the treatment and reference marshes was conducted prior to restoration (2005) and will continue for at least five years after restoration. Construction of the restored marsh at Elders East was completed in 2006–2007 and at Elders West in 2010. The monitoring program has been funded by the U.S. Army Corps of Engineers and the local cost-share partners (Port Authority of New York and New Jersey, New York State Department of Environmental Conservation, and New York City Department of Environmental Protection) and is managed and implemented by the National Park Service. Annual monitoring costs for each restoration project have been approximately $200,000.

This monitoring plan employs a BACI (Before, After, Control, Impact) design. Monitoring has been conducted at the restored marshes as well as at a control (JoCo) marsh, both "before" and "after" the restoration. The placement of dredge material and planting was the "Impact" and the undisturbed reference marsh (JoCo) was the "Control." The control marsh is representative of the target condition. We present and discuss planting treatments and results for some vegetation monitoring parameters at Elders East in this article.

Methods

Planting treatments

To expedite the establishment of salt-marsh vegetation at the restored marsh, vegetation plugs were planted and fertilized in 2006. In addition, some existing vegetation (hummocks) had to be relocated to accommodate project drainage and the delivery of fill at the project site. The hummocks and sediment were removed with intact root system and benthic communities by a skid loader and immediately placed in areas that had been filled to the design elevation (fig. 3). The objective was to evaluate the effectiveness of relocated hummocks for vegetative propagation.

Sampling design

Vegetation plots (1 square meter [1.2 sq yd]) were established along transects in 2005 (JoCo and pre-restoration Elders East) and 2006 (Elders East planted treatment and Elders East hummock relocation). The locations of each transect and of plots along each transect were established by a random-systematic design. At each plot, canopy

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Figure 3. Approximately 0.6 hectare (1.5 ac) of smooth cordgrass was the only vegetation remaining at Elders Point West before restoration. This species, which existed as hummocks, was excavated and distributed across 9.7 hectares (24 ac) during restoration construction, thus conserving the vegetation and associated benthos. The objective of this planting technique is to achieve revegetation of the restoration site via vegetative propagation and to accelerate the establishment of the marsh benthic community.

cover, species composition and abundance, total stem count, and plant height were measured. Paired with alternate vegetation plots, a clip plot and a soil core were collected to evaluate above- and belowground biomass. To evaluate net annual belowground production, in-growth cores were deployed in 2007–2009 and harvested during the subsequent fall; however, only data for samples harvested in 2008 are reported here. Because of the small size of the hummock relocation areas, no destructive sampling (clip plots or cores) was conducted for that treatment. All vegetation data and samples were collected during peak biomass (mid-August to October) each year.

Results and discussion

Planted plugs treatment (restored compared with reference marsh)

Vegetation monitoring at the restoration and reference marsh seeks to evaluate the response of vegetation to restoration and to determine if vegetation communities at the two marshes are converging. By 2008 total live vegetated cover (fig. 4, next page) and annual belowground production (table 1, next page) were equivalent. Furthermore, the project's interagency Monitoring and Adaptive Management Team had established a presumptive threshold of 50% vegetative cover by 2009; however, this goal was achieved by 2008. Failure to achieve the threshold would have triggered an evaluation and possible implementation of management actions to achieve the restoration goals. While total standing aboveground biomass and stem density did not differ between sites, on average, *S. alterniflora* plants are taller at the restoration site than at JoCo, the reference site. In addition, as it is a mature marsh, macro-organic matter at JoCo represents the long-term accumulation of belowground organic material; we observe that macro-organic matter at JoCo is greater than at Elders East.

Hummock relocation (Elders East planted treatment vs. Elders East relocation treatment)

The relocation of hummocks during restoration construction provided an opportunity to evaluate a method of vegetative propagation that also provides for the conservation of existing marsh vegetation and intact benthic communities while increasing the elevation at which the vegetation is growing. An additional year was required to achieve 50% canopy cover via vegetative propagation as compared with planting; however, by 2009, there was no difference

Table 1. Mean 2008 belowground biomass production[1] at two depth intervals at reference and restoration marshes

Depth	Reference (JoCo)	Restoration (Elders East Planted)
Belowground 0–10 cm (0–3.9 in)	262 ± SD 224 (n = 10)	274 ± SD 229 (n = 10)
Belowground 10–20 cm (3.9–7.9 in)	90 ± SD 193 (n = 11)	123 ± SD 146 (n = 10)

[1]Production measurements are in grams per square meter per year.
SD = Standard deviation

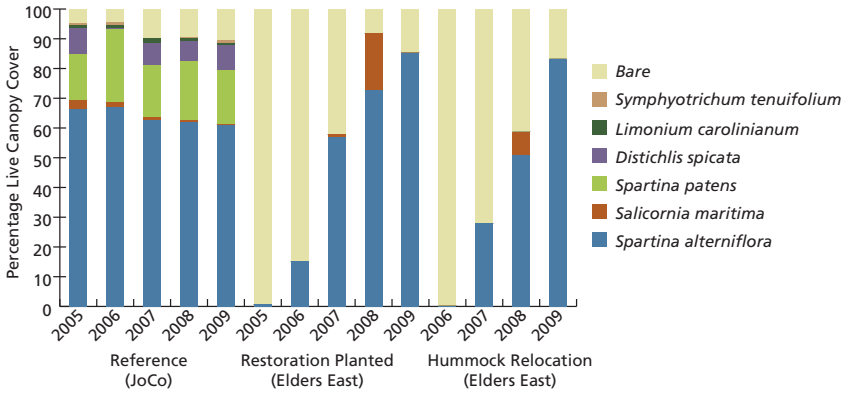

Figure 4. Mean live vegetative and bare canopy cover (as percentage of total canopy cover) by year for reference (JoCo treatment [n= 27]) and restored (Elders East planted treatment [n = 31]; Elders East relocation [n = 12]) marshes.

in canopy cover (fig. 4) or vegetative species composition, richness, or diversity.

Successes and lessons learned

As a result of the success of the limited hummock relocation at Elders East, hummock relocation was the planting technique employed over a 9.7-hectare (24 ac) area of the Elders West restoration (fig. 3, previous page). In addition, 1.7 hectares (4.2 ac) was planted in high marsh species (*S. patens* and *Distichlis spicata*), 1.6 hectares (4 ac) was left unvegetated to evaluate natural seedling success, and 0.4 hectare (1 ac) was seeded with *S. alterniflora*. Monitoring at Elders Point West will evaluate the efficacy of these planting methods for the establishment of vegetation and benthic communities. If natural recruitment or seeding proves successful in establishing vegetation at Elders West, then these methods can be used for future restoration projects in Jamaica Bay, eliminating the costs of *S. alterniflora* plant propagation, planting, or hummock relocation.

Both Big Egg and Elders Point East have demonstrated that we can successfully restore the saltmarsh form (i.e., the vegetation) in Jamaica Bay; however, it may be decades before we are able to determine if we have successfully restored marsh functions such as food web support and carbon sequestration. In addition, it is unclear whether or not Jamaica Bay marshes can be self-sustaining in the face of sea level rise, eutrophication, and inadequate sediment supply to the marsh surface. While much of the bay is within Gateway National Recreation Area, most of the impacts are historical or result from activities beyond park boundaries.

A principal success of the Jamaica Bay marsh restoration has been the development of a strong multiagency partnership that is working to restore the Jamaica Bay ecosystem. Working with partners has been key to advancing our understanding of marsh loss in Jamaica Bay as well as implementing marsh restoration and monitoring. Although multiple impacts associated with urbanization have reduced water quality, salt marshes, and other aquatic habitats, the bay's resilience provides an opportunity to focus on restoration of functions that are critical to ecosystem sustainability.

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