Salt intrusion monitoring in the Po River Delta branches (Italy)

Session HS1.1.10: Advancements in Adaptation and Mitigation Strategies for World's Deltas against the uprising climate hazards in the Anthropocene.

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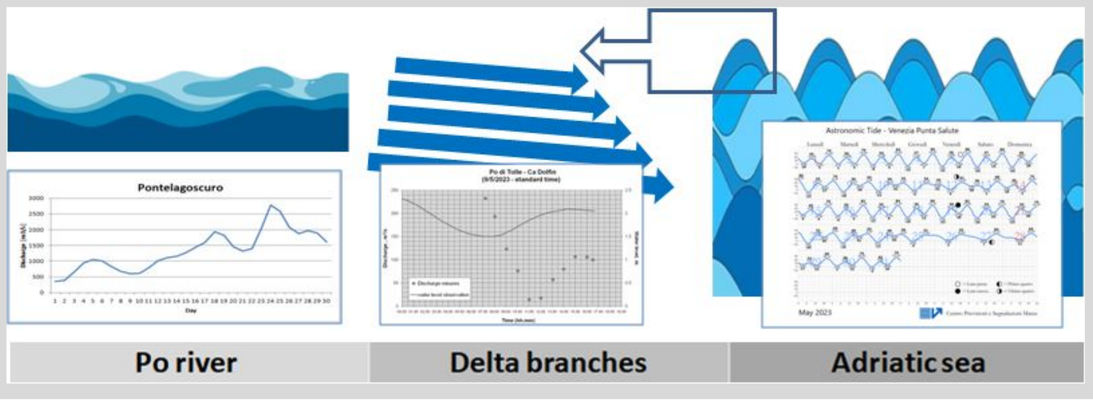
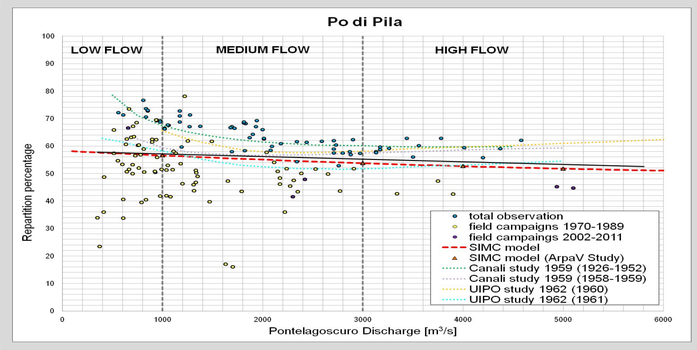
The Po River Delta is the outlet of the Po basin, the biggest catchment in Italy; it is composed of five branches Po di Goro, Po di Gnocca or Donzella, Po di Maistra, Po di Tolle and Po di Pila, spanning over a 700 km^2 area, nowadays inhabited by around 50.000. Modeled by the human presence through channels, levees and other hydraulic infrastructures, this is a "young territory", originated from the "Taglio di Porto Viro" done by the Republic of Venice, around 1600, in order to divert the Po river mouth southward and avoid silting of lagoon harbors. Beyond its high natural, economic and cultural value, this area is exposed to multiple hazards related to floods and storm surges, droughts, erosion, subsidence, water pollution and loss of biodiversity, exacerbated by soil consumption and climate change; one of the highest threats is the salinization of surface, groundwater and soils, due to the increasing of duration and extension of salt intrusion from the Adriatic Sea (Enhance, 2016; Allodi, 2022). Particularly during low flows, as in summer 2022 (GDO, 2022), salt intrusion reduces fresh water availability for drinking supply, agriculture and industry, as well as balancing habitat salinity and guaranteeing ecological benefits. For many years this fragile and dynamic context has been under systematic observation. A plethora of environmental variables related to salt intrusion, liquid discharges, solid transport, topography, hydrodynamics, tides and beach morphology (Visentini, 1940; Cati, 1981) have been collected through field and monitoring.

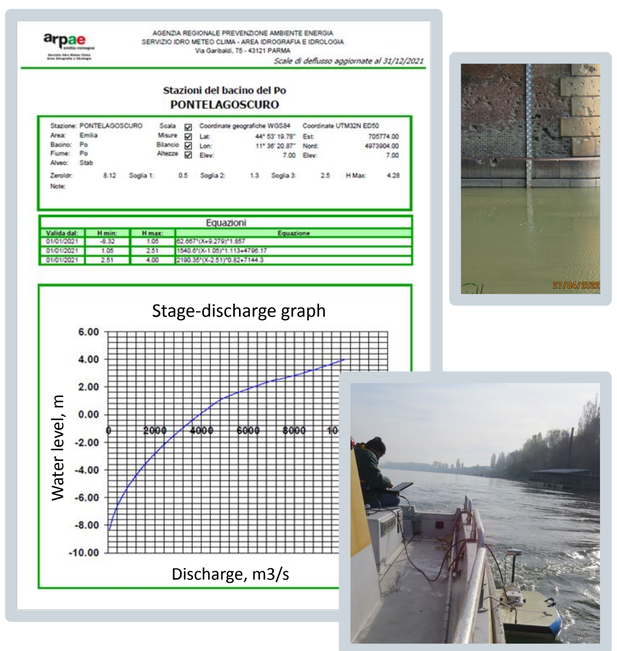
Upstream conditions (Pontelagoscuro)

Pontelagoscuro cross-section is located 91 km upstream the river mouth, collecting discharge from all the Po river tributaries; downstream the discharge is distributed in five delta branches.
The river cross-section which spans within the main levees, built between 1875 and 1890, is considered a stable cross-section. Water level observations started in 1807, nowadays they are collected through the telemetry network. Discharge field measurement started in 1922; nowadays mainly carried out with ADCP (Acoustic Doppler Current Profiler) technology.
Stage-discharge equations based on contemporary water level observations and discharge field measurements are also maintained since 1940. Their validity are slightly influenced by sea level tide excursions for discharge higher than 450 m^3/s.





Field campaign results in terms of repartition percentage of Pontelagoscuro discharge, Po di Pila branch - Low-High and Medium Flow conditions



Field activities for monitoring discharge repartition in Delta branches

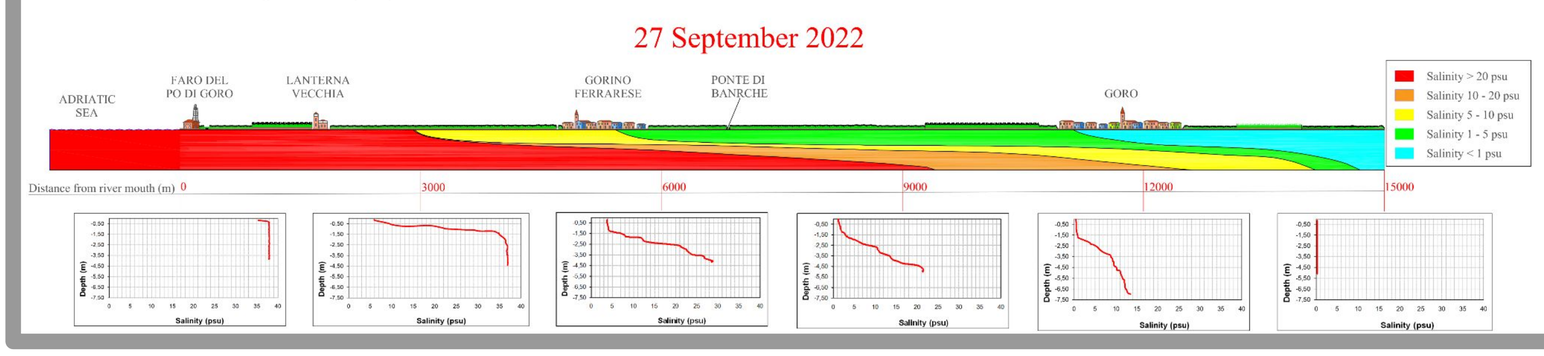
PLANNING	· selection of discharge based on hydrological predictions (Low - Medium or High flow); · selection of tidal conditions based on Astronomical tidal forecasts; · in situ inspection for verifying site equipment; · definition of measurement agenda based on tidal propagation upstream.
FIELD CAMPAIGN	· five measurement teams made of two people, one for each river delta branch, operate concurrently with a one hour time step following water level excursion, starting from the lowest water level and stopping after the highest level to investigate different tidal wave forcings; · downloading, validation and reporting of field data.
POST PROCESSING	· local water usage is also collected for calculating water balance; · discharge repartition percentage did not sum to 100 in the five delta branches, except in particular condition; · multiple factors affecting water balance are to be considered (unsteady upstream river conditions, hydraulics of each branch, dynamic effects of sea level excursion). Above described information is required when implementing discharge repartition equations in Delta branches (Po di Goro, Po di Tolle, Po di Gnocca or Donzella, Po di Maistra, Po di Pila).

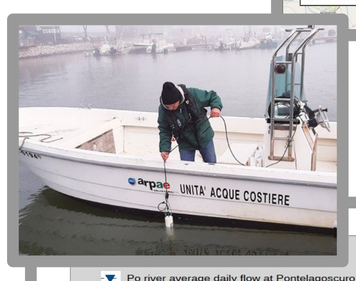
Discharge Repartition percentage in the Delta brances

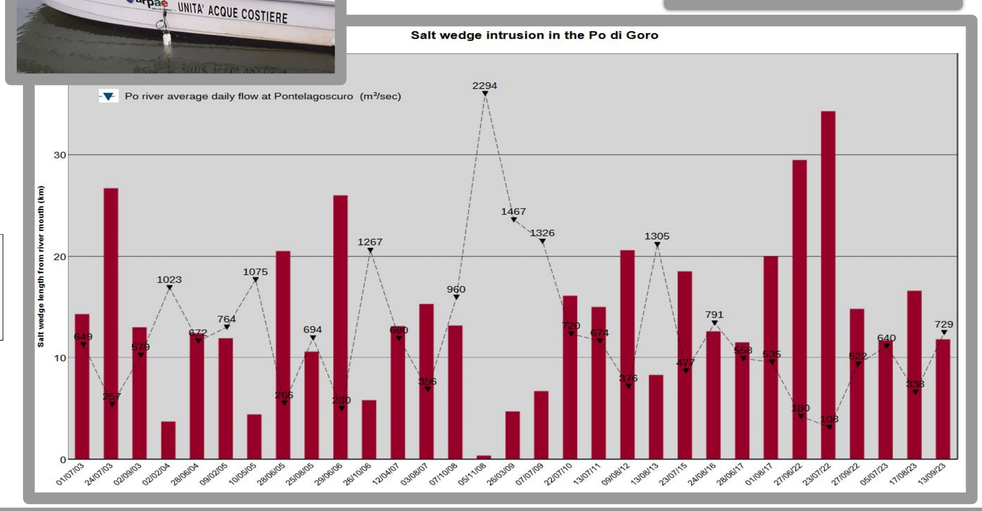
Fluvial Regime	Date	Po di Goro	Po di Gnocca	Po di Maistra	Po di Tolle	Po di Pila
Low Flow	about 1900	0.1	11.9	1	34	53
Low Flow	1926-1939	2.5	12.2	1.5	14.1	69.7
Low Flow	1958-1959	3.8	16	2.8	13	63.6
Low Flow	1970-1971	-	-	-	20.6	57.6
Medium Flow	about 1900	-	-	-	-	-
Medium Flow	1958-1959	7.6	16.3	3.4	12.1	60.6
Medium Flow	1970-1971	-	-	-	16.6	50.9
High Flow	about 1900	7	13	5	28	47
High Flow	1926-1939	9.3	12.6	2.3	15.9	59.9
High Flow	1958-1959	9.9	14.1	3.6	12.8	59.6

Field activities for monitoring the salt wedge

Since the beginning of XX° century salinity campaigns were carried out in the Delta area (Visentini, 1940). Recent field activities for monitoring the salt wedge in the Po river delta with modern technologies began in 2003, when Europe was hit by an exceptional heat wave in terms of both intensity and duration. The resulting drought forced the Environment Sector of the Province of Ferrara to begin the monitoring campaigns in the branches of the delta flowing into the Sacca di Goro, a transitional environment of considerable naturalistic importance and renowned for the production of clams. Subsequently these activities were carried out almost every year and were further extended to the other branches of the Delta (Po di Gnocca or Donzella, Po di Tolle, Po di Pila/Venezia). They essentially consist in measurements of salinity depth profiles recorded with a CTD multiprobe at defined distances from the river mouth. To track the maximum propagation of the salt wedge, the boundary between fresh and brackish water was assumed to be 1 psu. Since 2016 the monitoring campaigns are carried out by Arpae Emilia-Romagna. From the processing of the data collected so far, it emerges that the maximum intrusion of the salt wedge was recorded during the summer of 2022 when, in July, it reached peaks of 34.3 km in the Po di Goro and 40.1 km in the Po di Venezia corresponding to an average daily streamflow in Pontelagoscuro (FE) of about 110 m^3/s.







Outputs and Results

Firstly these monitoring activities serve to the purpose of maintaining the stage-discharge equations, particularly at the Pontelagoscuro Station upstream the delta, and consequently to maintain the discharge repartition equations in the delta, depending not only on upstream discharge but also on the hydraulics of each branch and sea level conditions (Settin, 2012); secondly, it is possible to deliver salt intrusion length assessment and estimation in each delta branch, which mainly depend on river discharges, their repartition in each delta branch and sea levels conditions (Comune, Turolla, 2023).

Territorial knowledge and conservation, based on the integration of in situ monitoring and control, historical data, other data sources (topography, groundwater, water quality), satellite products, models (including digital twins), artificial intelligence, uncertainties management and high computing capacities, may help to better understand earth systems and enhance simulation of future scenarios depending on climate, land use and social changes.
Therefore monitoring of the Po River Delta is indispensable for theoretical assessment, supporting from-short-to-long-term awareness, decision making and action by public institutions, private enterprises, associations and local community. The benefit are tangible, providing ecosystem services for sustainable and fair water uses in a vulnerable area exposed to increasing threats, but at the same time rich in opportunities and beauty.

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Sharing is encouraged

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