



## **Fast retreat of a barrier system due to reduced sediment supply (Bellocchio, Northern Adriatic Sea, Italy)**

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### **Abstract:**

The erosion issue is a constant threat along most of the littoral areas around the Mediterranean Sea. The Northern Adriatic Sea makes no exception, in particular the Emilia-Romagna region is subject to erosion processes that jeopardize human activities and natural ecosystems along large stretches of the coast. The factors responsible for the erosion processes are multiple and often depend on the characteristics of the site: the Bellocchio area can be considered as a case study for the landward retreat of a barrier system, caused by the decrease of sediment supply from the River Reno.

A series of aerial ortho-photographs was analyzed to define the evolution of the sector of coast comprised between the village of Porto Garibaldi to the north and the River Reno's mouth to the south. The photographs, spanning from 1942 to 2010, showed a severe landward migration of the whole system, in particular the area north of the river's mouth, where a large spit was progressively eroded and eventually disappeared. The recent evolution of the Bellocchio site is a further confirmation that a successful management of the littoral areas does not involve only coastal processes, but also the evolution of the sediment source feeding the beaches.

**Keywords:** Barrier system, Erosion, Sediment supply, Sediment transport, Shoreline migration, Aerial ortho-photograph, Northern Adriatic Sea.

### **1. Study area: the erosion issue at Bellocchio**

The Bellocchio site is located in the Emilia-Romagna Region facing the northern sector of the Adriatic Sea and is comprised between the village of Porto Garibaldi to the north and the River Reno's mouth to the south. The whole area is about 10 km long (see Figure 1). It is characterized by a strong morphologic variability, since there are smooth transitions between highly-anthropized sectors and natural beaches. The northern portion is mainly occupied by beach summer resorts. Towards the central sector human structures decrease and the area behind the beach is occupied by an artificial small fresh-water lake, named Lago di Spina. No human settlements are present along the southern sector towards the River Reno's mouth. This natural sector of the site can be considered part of a large barrier-lagoon system, since a wide lagoon is present about 2.5 km inland (Comacchio Lagoon) and there are brackish wetlands behind the

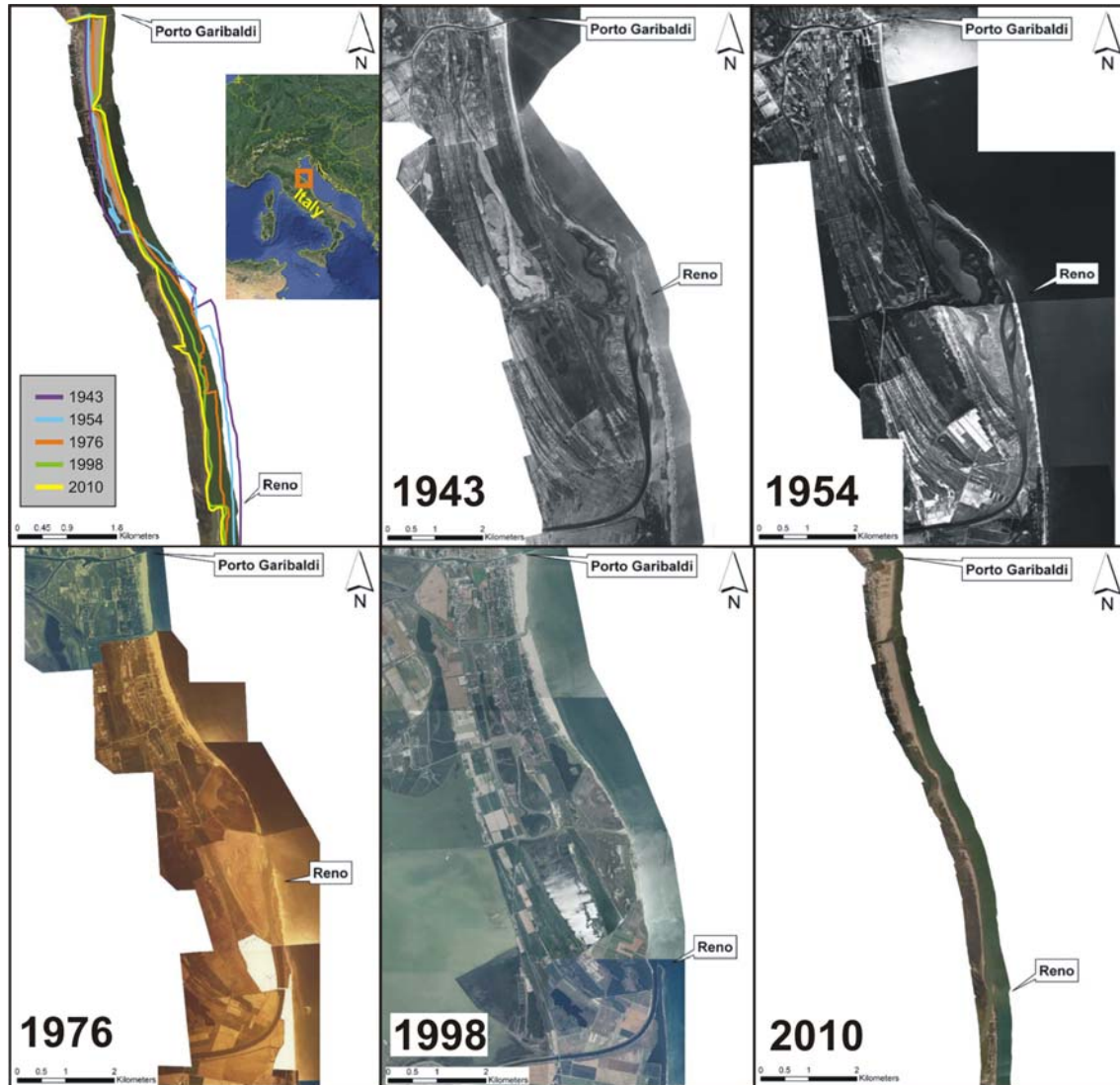
backshore. Longshore transport is directed northwards along this sector of the coast. The barrier corresponds to the beach that was built and fed by the sand brought to the sea by the River Reno, which is the only sediment source of the area. As occurring on most of the Italian Peninsula, the Bellocchio site is experiencing serious erosion processes that need to be addressed in order to reduce the landward migration of the system, which would lead to economic and ecological losses. Protection schemes involving the construction of wood groynes and, more recently, artificial replenishments have been set up to counteract the erosion impulse. However, the choice of the best-fitting intervention should be made also based on the recent evolution of the area. A series of aerial ortho-photographs spanning from 1943 to 2010 was studied to define the development of the Bellocchio site in the last 70 years. The results might be useful to improve future management and planning activities for this sector of the Adriatic coast.

## **2. Results and discussion**

In 1943 (RAF flight) the River Reno's mouth was located several kilometers to the north relative to the current position (see Figure 1). The final segment of the river was rotated northward and was separated from the sea by a large, 5 km long, spit. An emerging bar at the mouth implies that the river had a significant solid discharge. The lagoon behind the beach was large and comprised the area that at present is occupied by the brackish wetlands. North of the mouth the coastline assumed a cusped shape, likely determined by the considerable amount of sediments reaching the sea. The shoreline was interrupted by the inlet of the lagoon, whose entrance was partially obstructed by a small spit. Further to the north the coastline took a more regular configuration. In 1954 (GAI flight) the spit had already experienced an initial erosion impulse: the tip was eroded and the width was generally narrower than before. The trend is confirmed by the cusp north of the river mouth, whose shape was significantly smoothed with respect to 1943. The small spit at the lagoon inlet was entirely wiped out. However, erosion processes might have likely only just begun, because the sand bar at the river mouth was still present (see Figure 1).

Twenty years later, in 1976 (RER flight), the scenario was considerably different. A straight road was built south of the Lago di Spina in order to easily access the beach from an inland camping. The natural inlet previously active between the lagoon and the sea disappeared, having likely silted up by the sediments eroded from the cusp at the River Reno's mouth. To the south the erosion processes went on smoothing the shape of the cusp and reducing the size of the spit, which was about 1 km shorter than 20 years before (see Figure 1). Protection structures such as rip-rap slopes were built to protect the seaward side of the spit at River Reno's mouth, but they were not able to stop the erosion process. In 1998 (IT2000 flight) the evolution of the site did not experience a dramatic change. The River Reno's sediment discharge experienced a progressive decrease reaching very low values: about  $0.0018 \text{ kg}\cdot\text{m}^{-1}\cdot\text{s}^{-1}$  (PRECISO *et al.*, 2012); as a

consequence, the coast could not be fed by any source other than the progressive erosion of the cusp. Possibly testifying this decrease in sediment input, the spit was hardly visible in 2010 and nowadays virtually no more existent. The coastline, once so prominent into the sea due to the presence of the large cusp, was almost rectified in 2010.



*Figure 1. Aerial ortho-photographs of the study area from 1943 to 2010; the evolution of the coastline during the years is showed in the top left map.*

The sediments coming from the south determined the frequent obstruction and consequent silting up of the inlet that ensures water exchange between the Comacchio Lagoon and the open sea. In addition, the regularity the coastline reached around the mid-2000 years was only interrupted by the protection structures (wood and block groynes) built in the central sector of the site to protect a summer resort

(NORDSTROM *et al.*, 2015). The wood groynes trapped the sediments preventing coastline retreat in that area, but at the same time shifted the erosion impulse to the coastal sector immediately to the north.

### **3. Conclusions**

In conclusion, the present geomorphological configuration at the Bellocchio site is not particularly different from that of 2010. The northern sector benefits from the sediments coming from the south, still subjected to erosion. The protection structures built to protect the summer resort, interfering with the natural dynamics of the site, determined the formation of a bulge: immediately to the north and at the bulge the beaches are maintained through artificial back-passing practices, southwards from the bulge, the beach is migrating landward. The harsh diminution of sediment supply delivered by the River Reno during the last decades triggered the initial erosion processes, which at first were partially compensated by the erosion of the wide spit at the mouth. The sand eroded from the spit concurred to feed the beaches northwards, ultimately leading to a fast destruction of the spit itself. Once this secondary source of sediment was wiped out, the River Reno regained the status of being the only source supplying sediment to the sea, with a virtually negligible solid discharge. As a consequence, the beach erosion is not counteracted by natural processes, leaving artificial replenishments the most likely option to prevent further landward migration of the barrier system, which would jeopardize the ecological value of this area.

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