ISSN (print): 1698-6180. ISSN (online): 1886-7995
www.ucm.es/info/estratig/journal.htm

Journal of Iberian Geology 34 (2) 2008: 167-190

Journal of Iberian Geology
AN INTERNATIONAL PUBLICATION OF EARTH SCIENCES

Man's Impact on the Coastline

Impacto humano sobre la zona costera

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Received: 15/03/07 / Accepted: 24/09/07

Abstract

The coastline is important to man as a site of settlement, commercial, industrial and leisure activity and is likely to be important for the production of energy in the future. It has been greatly affected by human activity. Coastal protection schemes, stabilisation of channels in estuaries and on deltas, reclamation and urbanisation have produced profound changes, often with unexpected results. Also, human activities in the drainage basins of the adjacent hinterland have had important consequences on the coasts by influencing the supply of sediment, nutrient and pollutants. Climatic and sea level changes are likely to greatly affect this vulnerable zone in the future.

Keywords: coastline changes, human impact, erosion, reclamation, pollution, hinterland, sediment supply

Resumen

La zona costera es importante para el ser humano como área de asentamiento y para el desarrollo de actividades comerciales, industriales y de esparcimiento; asimismo, será importante en un futuro para la producción de energía. Sin embargo, esta zona ha sufrido importantes afecciones derivadas de la actividad humana. Proyectos de protección costera, de estabilización de canales en estuarios y deltas, y la ocupación y urbanización de espacios costeros han provocado cambios profundos, a menudo, con resultados inesperados. Igualmente, las actividades humanas en las cuencas de drenaje de las zonas continentales adyacentes tienen consecuencias importantes sobre la costa, incidiendo sobre el suministro de sedimento, nutrientes y contaminantes. Las variaciones climáticas y del nivel marino probablemente afectarán en el futuro de modo importante a esta zona tan vulnerable.

Palabras clave: cambios costeros, impacto humano, erosión, ocupación, contaminación, aporte de sedimento continental.

1. Introduction

The coast is an important part of man´s heritage which has inspired writers, painters and musicians. From a more practical point of view it is important as a site of habitation; 70% of the world´s population are predicted to be residing in the area adjacent to the coast in the next century (Haq, 1997). Also, it is the location for vast commercial and industrial developments. The coastal ports act as a link for the movement of goods overland and by sea between far distant countries. In addition, the rivers which flow to the coast are important arteries which connect the coast with the innermost parts of many countries.

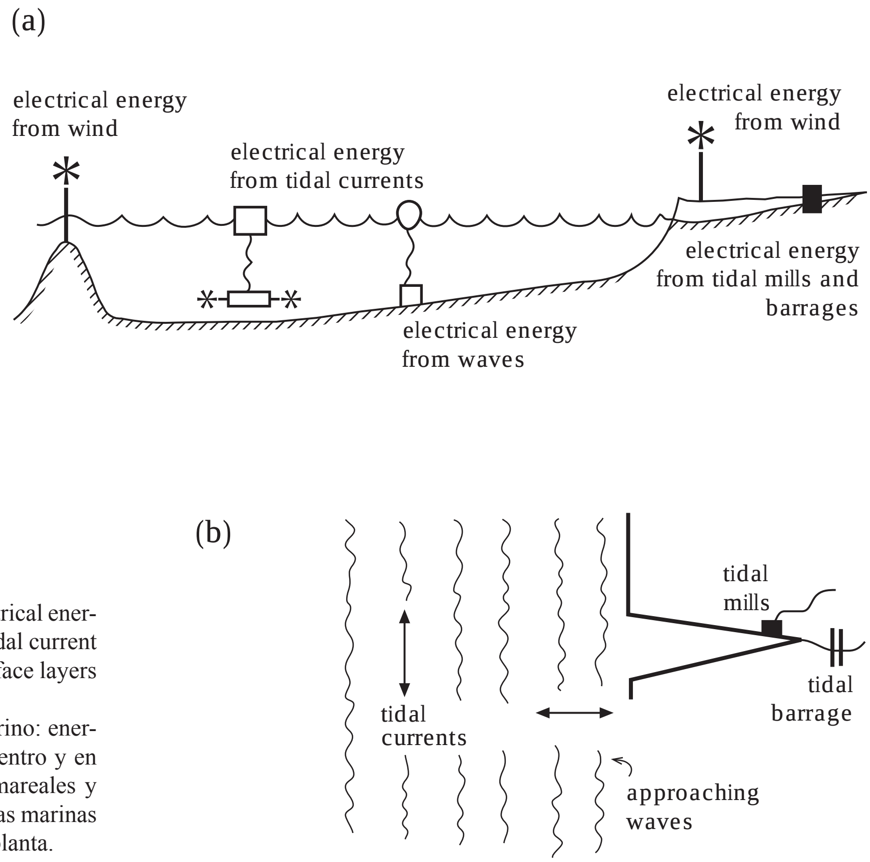

Fig. 1.- Various sources of energy from the sea: electrical energy from offshore and land turbines; submerged tidal current turbines and wave energy trapping-screens in surface layers of the sea. (a) section: sea/land, (b) plan view.

Fig. 1.- Diferentes fuentes de energía de origen marino: energía eléctrica a partir de turbinas situadas mar adentro y en tierra firme; turbinas sumergidas de corrientes mareales y pantallas captadoras de energía de las olas en zonas marinas superficiales. (a) sección mar/tierra, (b) vista en planta.

The coast is also important as a base for the fishing industry and, recently, for fish farming. Coastal plains are the site of a flourishing agricultural industry with extensive cultivation of crops such as rice and cotton. Extraction of salt for human consumption and the collection of algae for fertilization of the land are important at some locations.

With the growing prosperity of many nations, tourism has become the most lucrative activity for many undeveloped countries, as well as for the richer countries.

In the past, tidal-mills utilized the power of the tides (there is still a tidal mill operating in Southampton Water; the only one in the U.K.) and windmills that of the wind. In recent decades there has been increasing interest in once again utilizing wind, wave and tidal power; this is likely to increase in the future (Fig.1). Wind farms are being constructed at coastal and offshore situations. Although, at present, the only attempts to utilize tidal power, on a large scale, has been in the Rance estuary, France and in Canada;others were planned in Russia, India and Korea, but have not yet been constructed (Wilson,1979; Amos, personal communication). However, discussions are once again taking place in countries such as Great Britain to construct new large barrages at sites such as on the Severn Estuary, UK (Pearce, 2006).

Already man has had a great impact on the coastlines of the world: he has destroyed the natural beauty of large stretches of coastline and, unfortunately, has rarely improved its appearance. Man´s activities have caused erosion, sedimentation and has polluted huge areas, by careless disposal of human and industrial waste. Excessive extraction of oil, gas and water and the construction of large buildings has caused land subsidence along the coastal plains and has increased the scale of flooding. Over-extraction of water from coastal plain sediments has led to the intrusion of salt water into coastal aquifers. Furthermore, if, as is accepted by the majority of the scientific community, the increase in the world´s temperature and the changing pattern of rainfall is due to Man´s activities (Zhang *et al.*, 2007), he has produced many problems as well as increasing the risk of river flooding and the likely future inundation of huge areas of coastal plains.

However, not everyone is convinced that there is a problem with climatic changes and the associated rise of sea level! (Fig.2).

Even human activities which have taken place far from the coast impinge on the coastal zone. The construction of dams for irrigation and hydro-electric power, as well as changing patterns of agriculture and deforestation,

Fig. 2.- Some people are doubtful about the generally-accepted view and danger of global warming and sea-level rise (cartoon by Dave Brown in *The Independent* newspaper. Reproduced with kind permission of The Independent).

Fig. 2.- Algunas personas son reticentes hacia las ideas generalmente aceptadas sobre los peligros del calentamiento global y el ascenso en el nivel marino (viñeta de Dave Brown en el diario The Independent. Reproducida aquí con el permiso de *The Independent*)

have produced dramatic results in the coastal areas due to the interference of the flux of water and sediments from the land to the sea.

In general, the problem is always the same; it has resulted from the fact that it has not been appreciated that the coast and its hinterland are linked dynamic environments, which are interrelated. Also, many coastal changes and processes are cyclical and are inconvenient to man, who, from a mangement and engineering perspective, prefers a more stable unchanging environment. Unfortunately, large scale human interference has so often produced unexpected and very costly consequences.

2. Sources of Coastal Sediment

Coasts formed of hard resistant rocks suffer least from the impact of man but elsewhere his activities have produced dramatic changes. Other than being colonised on their crests, cliffed coastlines have largely escaped human modification. However, in some areas they have been mined for building stone eg. in Jersey, Channel Islands, where the cliffs of the Ecrehous Islands were once quarried for building stone (Mourant, 1956). Also, cliffs were modified by the military in Gibraltar where they were steepened by the British Army to stop invaders scaling them (Rose, 2005).

The stability of many coastlines depends upon the uninterrupted supply and distribution of sediment; this produces the wide range of coastal types, e.g: beaches and dunes, barriers enclosing lagoons and estuaries and deltas. Although the erosion of cliffs composed of soft sediment provides large amounts of sediment e.g. the erosion of the soft glacial sediments on the eastern coast of England (Steers,1948).Generally, the major part of coastal sediment is supplied by rivers. It is distributed along the coastline to form beaches and dunes, to enclose lagoons or to infill embayments and estuaries (Fig.3).

In addition, in some areas, sediment is moved shorewards from the adjacent sea floor of the inner continental shelf by waves and currents. However, sediment is lost to the offshore areas during storms, but normally this is returned during calm more normal conditions.

Wind drives the coastal sediment landwards from the beaches to form extensive dune complexes. The landward escape of sand from the coast has been reduced or stopped in some areas by the planting of trees. Along the Aquitaine coast in southwestern France, extensive tree

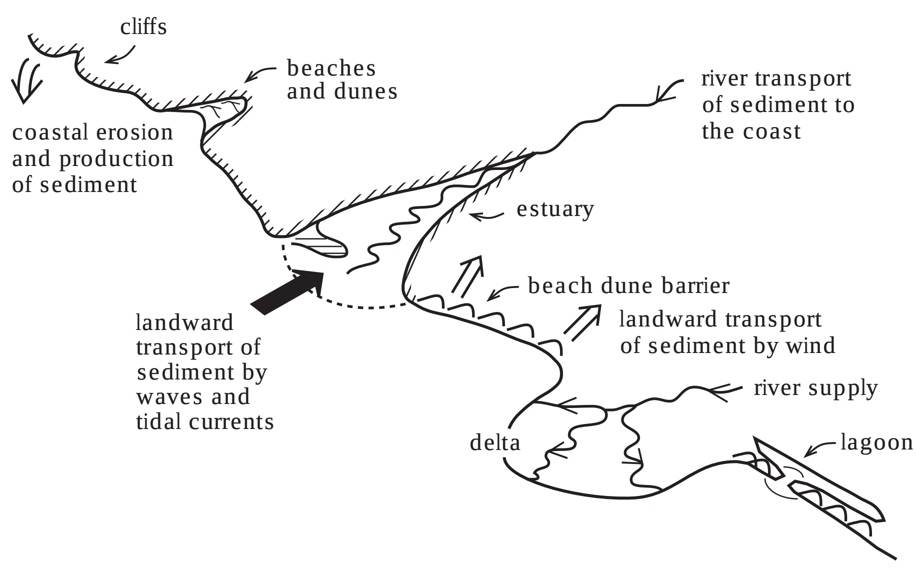

Fig. 3.- The main coastal geomorphological features and various sources of sediment together with the principal agents of sediment dispersal along the coastline.

Fig. 3.- Principales características geomorfológicas costeras y diferentes fuentes de sedimentos junto con los principales agentes de dispersión sedimentaria a lo largo de la costa.

planting has led to the forest area doubling from 127,000 ha to 225,000 ha between 1821 and the 1930s and to the building of high coastal dunes such as the Dune de Pyla (113m) (Clout, 1980, 1983). Conversely, when it is dominantly an offshore directed wind, e.g. in Qatar, Arabian Gulf, this can be an important source of coastal beach sand (Shinn,1973).

The natural supply of sediment is sometimes augumented by direct dumping of building and mining waste on the beaches e.g. on the north eastern coast of England where coal-mining waste was deposited extensively on the beaches during the 19th and 20th centuries (Steers, 1948).

Elsewhere, although of less importance volumetrically; in the past ships often dumped ballast on beaches. On the southwestern coast of Wales. Ships, coming for coal, arrived carrying ballast of rock and sand for stability during passage; this was emptied onto the local beaches, before they were filled with their load of coal (Howells, 2003). Similarly, English ships dumped ballast on the eastern coast of the USA, before filling their holds with cargoes of economic products to be exported to England. This resulted in a wide variety of English rocks (i.e. exotic rocks) being used in the building of the quays of some American ports.

In some areas, more commonly in the past, but which is now generally prevented by legislation in most countries, sand and gravel has been removed directly from beaches by man either for the construction industry, for infill of reclamations, or for less common reasons,such as modifying beach profiles for military operations e.g. in Amroth, southwestern Wales (Howells, personal communication). Large quantities of sand were removed from the beaches and intertidal zones for the construction of military defences in the Channel Islands, particularly in Jersey, during World War II (Ginns, 1973; Bishop and Bisson, 1989).

At Hallsands, Devon UK, 395 x10^{3} cubic metres of beach sand and gravel were removed between 1897-1902 for the construction of Plymouth docks; this lowered the beach which was not replenished by natural processes. Consequently, during a storm in 1917, the complete village was destroyed (Worth, 1904; Hails, 1975) (Fig. 4). Unfortunately, in spite of the lesson of the past such mining and removal of beach sand for construction purposes is still a common practice in some countries, e.g. Nigeria (Ibe, 1988). Also, beaches are still extensively disturbed and some sand removed during the extraction of placer mineral deposits in many parts of the world e.g., Africa, India and Southeast Asia.

More important than these activities, is the loss of beach sand by the construction of dams on the supplying streams and rivers. The loss of beach sand produced by such constructions in Southern California, USA, was first realized by Grant (1938). Legal action was taken by local governments against the builders of dams, as these resulted in the depletion of beaches, whose presence attracted many tourists (Norris, 1964).

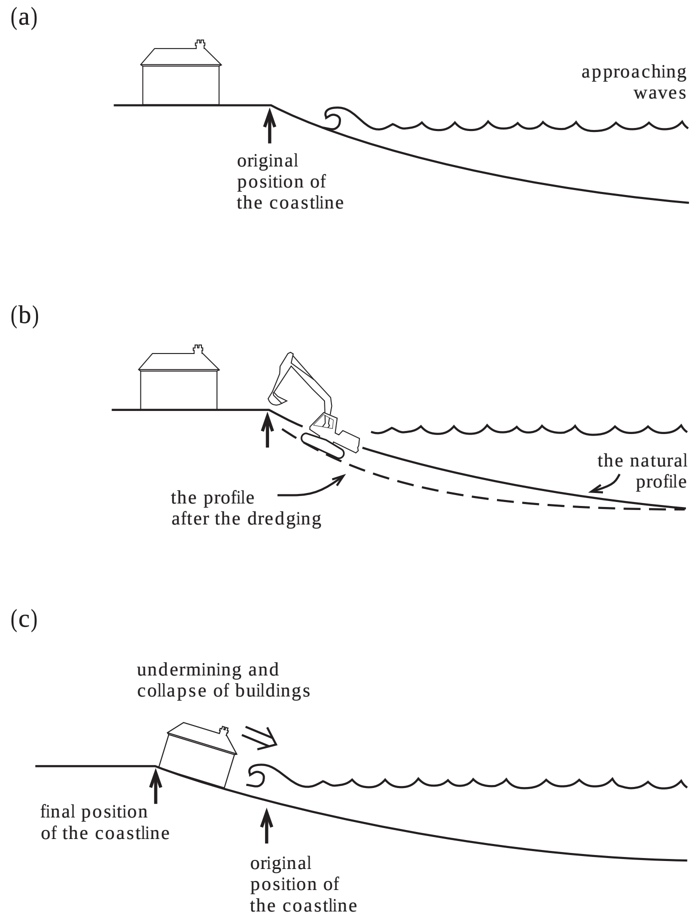

Fig. 4.- The consequences of steepening beach-nearshore profiles :(a) original profile, (b) dredged profile, (c) re-establishment of profile and associated coastal erosion.

Fig. 4.- Consecuencias de la profundización de los perfiles costeros y de playa: (a) perfil original, (b) perfil dragado, (c) restablecimiento del perfil y erosión costera asociada.

3. Beach-dune and barrier coastlines

Many coastlines are occupied by beaches which are often succeeded landwards by dunes. Sand or gravel is moved by a hydrodynamic system. Waves affect the sea floor particularly in the nearshore zone; where they approach the coastline and break in the shallowing waters. Normally, beaches react to changing wave climate which is usually seasonal and punctuated by periods of intense storms. Sand and gravel is moved landward during periods of low- wave steepness (normally summer) and seaward during periods of high- wave steepness (normally winter).

Where waves approach the coast obliquely the beach sediment is moved alongshore in a direction determined by the dominant wave approach (Johnson, 1956; Inman and Frautschy, 1966; Silvester, 1950).

The sand may originate in the offshore zone from deposits formed at lower sea levels, by the breakdown of shells to produce skeletal sands or more rarely by precipitation of calcium carbonate to produce oolitic sands. Elsewhere, they may have been produced by erosion of cliffs composed of soft sediment located landward of the beach, along the shoreline, or from river sources.

In some situations, where the erosion of cliffs composed of soft sediments is the source, this may be cut-off by the construction of a seawall to protect habitations unwisely built on the cliffs to enjoy fine sea views and subsequently have been threatened by erosion. This procedure, although preventing cliff erosion, produces erosion alongshore due to the cessation of the supply of sediment (Fig.5a). Elsewhere, where sand is in short supply or has been disappearing due to coastal erosion, it is common to prevent alongshore transport and produce a local “build-up” of the beach, by the construction of groynes. Such structures do indeed retain sand locally, but they also reduce or may prevent its alongshore movement; thus inevitably causing erosion alongshore (Fig.5b.)

Similarly, when a breakwater is constructed to provide shelter for boats, it interferes with the alongshore transport of sediment. Because the water in front of the construction is too deep for the waves to break, they are merely reflected offshore and do not induce alongshore transport. Instead the sand is deposited on the landward extremity of the breakwater. However, ultimately as its deposition produces shallower water; waves will then break and, gradually, sand will be driven along the breakwater and finally spill into the quiet sheltered water of the harbour (Fig.5c). If left uninterfered with this process would gradually close the harbour entrance. Clearly, this is not allowed to occur and the sand is removed by dredging, e.g. in Santa Barbara California USA (Johnson, 1956). Downdrift, alongshore from the breakwater, erosion occurs as the normal alongshore supply of sand has ceased.

A similar situation occurs, when a deep channel has been cut across the nearshore zone, to allow access for boats to enter a harbour. Whereas waves break on either side of the channel, within the channel itself, due to the presence of deep water, the waves will continue to advance into the harbour unhindered. They will, however, be diffracted and reflected by the harbour walls. Consequently, the transport of sand terminates at the updrift side of the channel and it spills into the channel until it is removed by dredging. The interruption of alongshore

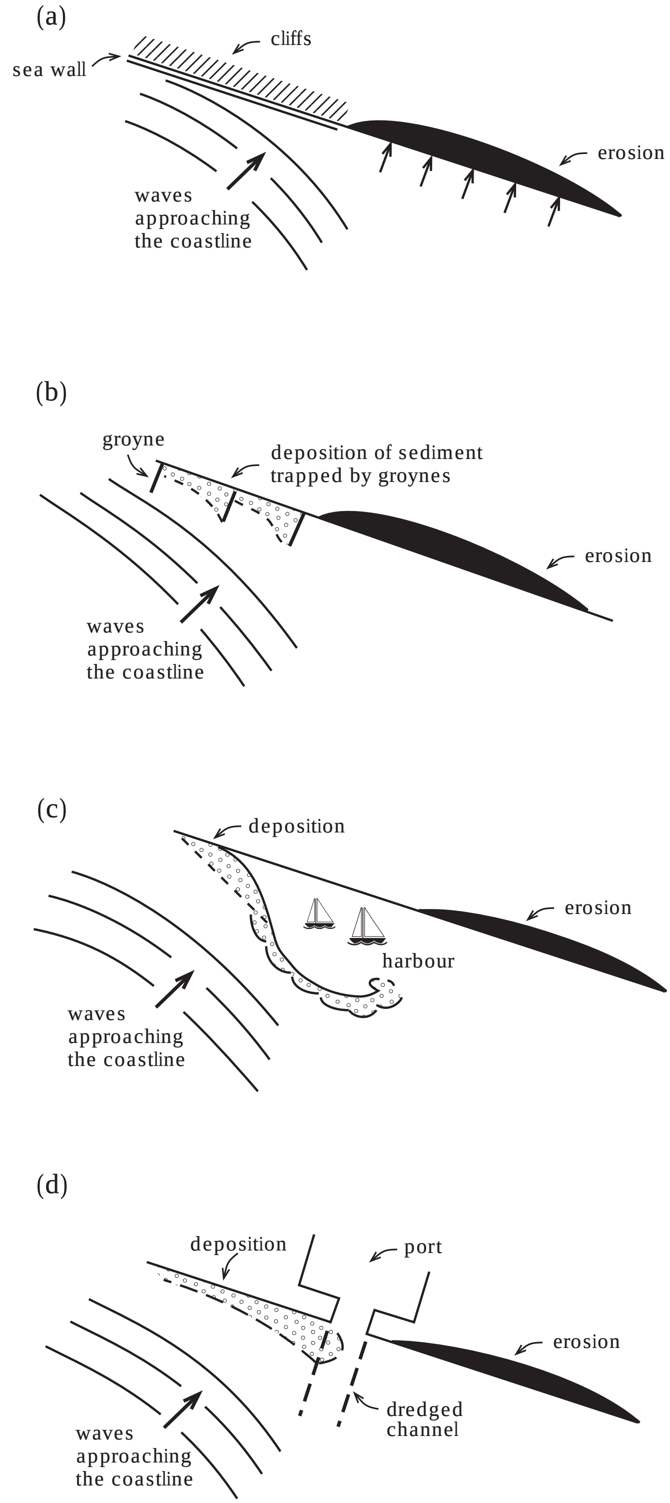

Fig. 5.- Examples of man induced erosion on wave-dominated coastlines: (a) construction of sea walls, (b) emplacement of groynes, (c) construction of a breakwater in the nearshore-zone, (d) dredging of a channel across the nearshore-zone.

Fig. 5.- Ejemplos de erosión provocada por el hombre en costas dominadas por el oleaje: (a) construcción de diques, (b) localización de espigones, (c) construcción de un rompeolas cerca de la orilla, (d) dragado de un canal cerca de la orilla.

supply again causes erosion on the downdrift side of the channel (Fig.5d).

In all the cases outlined above, the only solution to erosion caused by man´s interference of the natural system, is to feed the eroding beaches with sand from offshore, or to artificially transfer sand from where it is being deposited and to return it updrift of the various obstructions, either by pumping or transferring it by vehicles (Finkl and Walker, 2002). More rarely, expensive offshore breakwaters have been constructed to protect vulnerable coasts.

In many cases, eroding coastlines have been protected by "hard structures" such as sea -walls. These have sometimes been constructed for military purposes. During World War II the Germans constructed extensive sea walls and gun emplacements along the western coast of Europe as a defence against Allied landings. Similarly, extensive defence structures were built around the Channel Islands. These were constructed by slave-labour under the direction of TODT, consisting of mainly Russia prisoners together with many Spanish Republicans and left -wing French Prisoners, who lived and worked under atrocious conditions (Rose, 2005). Sea-walls have not always been as protective as had been originally hoped. They produce wave reflection and increased turbulence, which in turn, induces large amounts of sand to be raised into suspension and erosion to occur at the base of the sea wall. Nevertheless, they were shown by Krause and McDorigal (1996) not to produce such a loss of beach sand as once had been assumed would occur, unless the waves approach the coast obliquely, when the increased sand in suspension can be easily transported alongshore away from the coast protected by sea walls and cause erosion. The construction of sea walls has occured for a variety of reasons, as well as to protect the coast from erosion. There was extensive development of coastal railways in western Europe, particularly in the XIX century. These were constructed along the coastline not only to afford the passengers fine panoramas, but also to avoid the need of the constructions of costly bridges and the excavation of tunnels and cuttings, if they had been sited inland, as was the case in southern Devonshire, UK. Such railways were protected by extensive seawalls and boulder ramparts which still remain an important part of the coastal protection.

Beach-dune barriers (barrier islands), composed of sand and gravel, enclose lagoons along many coastlines of the world. They are particularly well developed along the eastern coast of the USA as well as in Holland, Portugal, the southern coast of France etc. Such barriers are cut normally by tidal inlets, which often migrate alongshore and provide access for marine water to the enclosed lagoons to landward (Pilkey, 2003). Under natural conditions, many barriers migrate landwards by overwash during storms, unless they receive sufficient sediment to counteract the Holocene sea -level rise and this movement has accelerated in recent years (Fig.6a).

Barrier islands have become extensively colonized with the construction of holiday beach houses and in other places, such as Florida, southern France and southeastern Spain etc., with a dense cover of more permanent dwellings; of course these are accompanied by the construction of roads and bridges, and small harbours and channels have been excavated on their landward sides (Fig.6b).

A great deal of effort has been expended to preserve such buildings and their infrastructure against the sea: by attempting to stabilize the islands with the construction of groynes, sea-walls and also by the stabilization of inlets by dredging, the construction of training walls and the importation and dumping of sand to replenish that lost during storms. However, this is very expensive and many dwellings, which have been destroyed during storms, have been abandoned (Fig.6c). The fragility of the situation was well illustrated by the storm of 1962 which occured on the eastern coast of the USA, when many lives were lost together with > \$300 x 10^6 worth of damage (Dolan *et al.*, 1973; Dolan and Lins, 1975; Kaufman and Pilkey, 1983). However, these measures are unlikely to succeed against a constant rise in sea level. Such developments are being restricted or forbidden in some localities but much of the damage is already irreparable (Davis and Bernard, 2000).

The cost of remedial work and coastal protection is too large in many areas for private individuals to bear; much to the distress of many home owners, private insurance companies and even state and National governments are becoming reluctant to pay for the re-establishment of these homes, unless the importance of a development has made this imperative (Kaufman and Pilkey, 1983).

4. Estuaries

The drowning of the lower courses of river valleys during the Holocene has led to large landwards extensions of the sea (rías). In these, as well as in river mouths of deltas, marine and freshwater encounter one another to produce mixed or layered estuarine circulations.

Sediment is delivered to estuaries by the inflowing rivers, from alongshore by littoral drift or from the adjacent sea floor from whence it is driven landward by waves and, in tidal seas, by currents. The entrances of these features are often partially closed by sand and gravel beaches and sand-dune barriers.

Where abundant sediment is available their sheltered parts are occupied by sandflats, mudflats, marshes and swamps (Fig.7a).

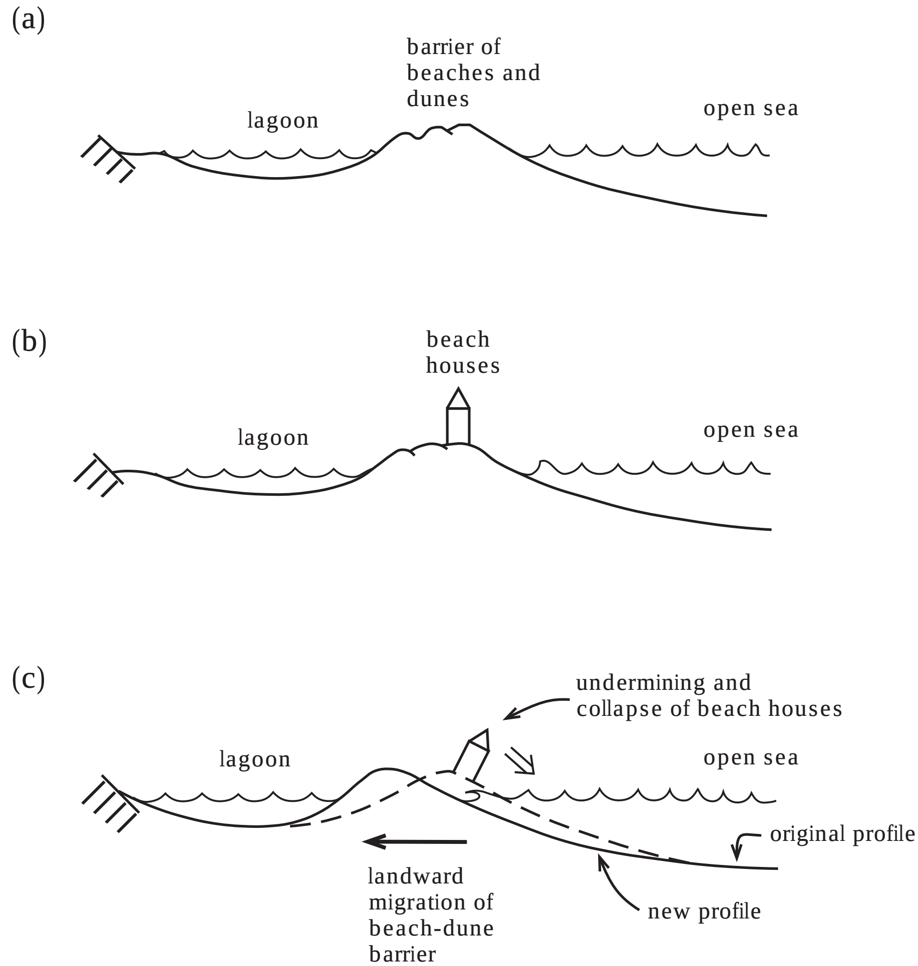

Fig. 6.- Barrier-beach coastline: (a) a typical natural profile, (b) urbanization, (c) property destruction as a result of landward migration of the barriers.

Fig. 6.- Zona costera con playa-barrera: (a) perfil típico, (b) urbanización, (c) destrucción de propiedades como consecuencia de la migración tierra adentro de las barreras.

Estuaries are the site of villages, towns and some of the world´s largest cities together with their harbours and related industrial complexes. Consequently, they have been modified extensively by man. Engineering works have resulted in a reduced capacity (i.e. they have become infilled with sediment) of many estuaries e.g. The Lune, Ribble and Mersey, U.K. (O'Connor, 1987). Channels in which the river and sea- water flow and mix are unstable and migrate across the estuary under natural conditions following cyclical patterns of months or years (Inglis and Kestner, 1958; Zengcui and Zeheng, 2002). Such channel instability is inconvenient for ship movements as the buoys marking the channels have to be constantly moved, particularly in high range tidal areas such as the North Sea. Attempts have been made to stabilize the channels by the construction of training walls (Fig.7b). However, whereas such walls have restricted channel movements and, in areas such as the Mersey estuary leading to the port of Liverpool U.K., have led to deepening and increased velocities in the channels in parts of the estuary. They have produced increased siltation in the inner estuary, a diminution of capacity and also of the tidal prism. In spite of extensive dredging between 1897-1955, when 306 x 10^6 cubic metres were removed, the Mersey estuary decreased its capacity by 10% between 1861-1960 (Price and Kendrick, 1963).

Similar changes occurred in The Lune estuary on the Lancashire coast UK, where the restriction of movement of the channels led to a 47% loss of capacity between 1838-1844 and 1955-1956. Such changes have been exacerbated, in many estuaries, by the diversion of incoming streams, bridge constructions and the tipping of industrial waste; these have all led to a diminution of tidal flow.

An increase in the size of vessels using harbours and estuaries has led to the necessity for the maintenance of increased water depths in the main channels; this, in turn, has resulted in continual and costly dredging, which has been accompanied by the problem of the disposal of the dredged material. Sometimes sediment removed from estuaries has been dumped in the adjacent marine areas; often this has proved ineffective and for example in the Thames estuary UK this material has been returned by the tidal flows to the estuary within a short time (Inglis and Kestner, 1958).

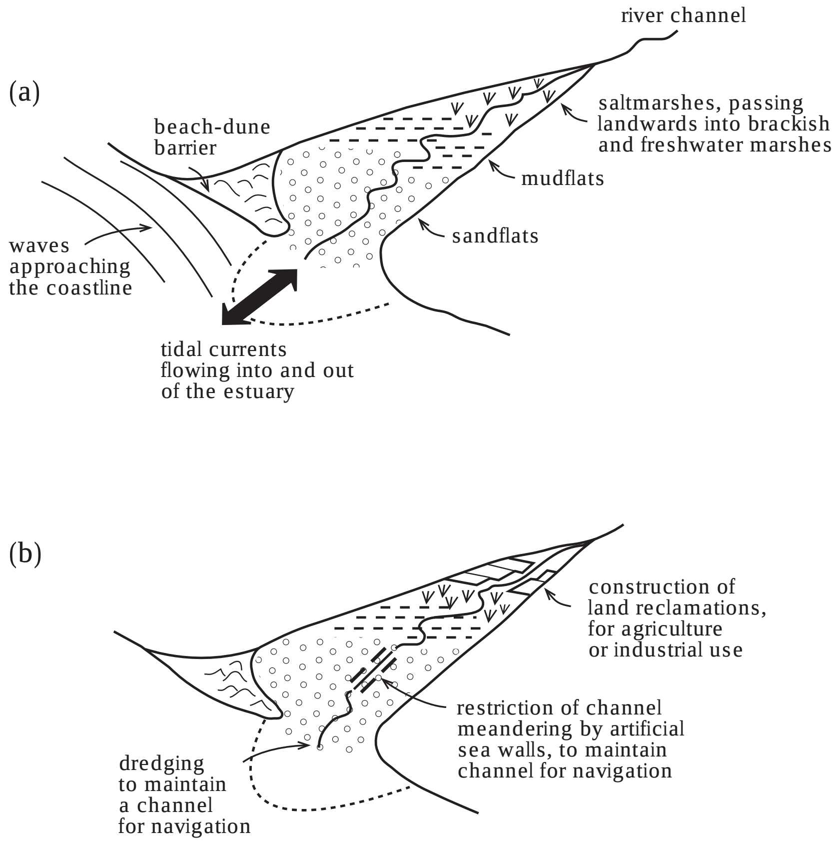

Fig.7.- Estuaries, together with typical modifications by man: (a) estuary with major elements and principal processes, (b) common examples of man's activities in estuaries

Fig. 7.- Estuarios y típicas modificaciones humanas: (a) estuario con sus principales elementos y procesos, (b) ejemplos comunes de actividades humanas en los estuarios.

The situation has been made more difficult as natural infilling of estuaries has occurred over historical times, in some areas in northern Europe, due to the abundance of sediment in the offshore zone and the presence of strong tidal currents which have driven the sand landwards from the adjacent continental shelf.

5. Land reclamation

The enclosure of areas covered normally by the sea for agriculture has occurred in many parts of the world, particularly in North West European countries (e.g. Holland, Germany, Denmark and Great Britain) bordering the North Sea (Wagret, 1968; Verger, 1985). This has taken place on the margins of estuaries, large lagoons such as the Wadden Sea, The Netherlands and elsewhere around large coastal embayments. More than 30,000 hectares have been reclaimed around the shorelines of the Wash, a large embayment on the eastern coast of England, since Saxon times (Darby, 1940). Here, as in many other areas of large tidal range, the coast is bordered by wide intertidal flats; these from low-water to high-water mark, are covered by sandflats, mudflats and salt marshes (Fig.8a). When undisturbed these environments would naturally grade into brackish and finally freshwater swamps of dense woodland (carr).

In such areas, sea- walls have been constructed over long periods to exclude the tidal waters and to enable the land to be cultivated (Darby,1940; Evans and Collins, 1987) (Fig.8b). Normally, it takes two or three years of exposure to rainfall for the enclosed land to be free of salt and ready for cultivation. This reclaimed land is very fertile and its recovery from the sea has brought great benefits to local landowners and coastal communities.

However, extensive enclosures have resulted in the narrowing of the remaining intertidal zone and the depletion of the areas of natural habitat for the indigenous fauna and flora, as well as for the large flocks of migratory birds which visit such areas annually.

Drainage, wastage of the surface due to oxidation of the organic matter of the sediments, which are normally rich in this component, and the passage of heavy farm-vehicles, have lead to the lowering of the surface level of the reclaimed land to below that of the contemporary salt marshes on the seaward of the enclosing sea walls (Fig.8c). Reclaimed land in parts of the Netherlands has subsided by 10-100 cm in 25 years following reclamation and drainage (Glopper, 1973). Elsewhere, Petzelberger (2000) suggested that reclamation on the northern coast of Germany and the subsequent lowering of the surface, led to the increase in severity of the floods experienced in the Late Middle Ages.

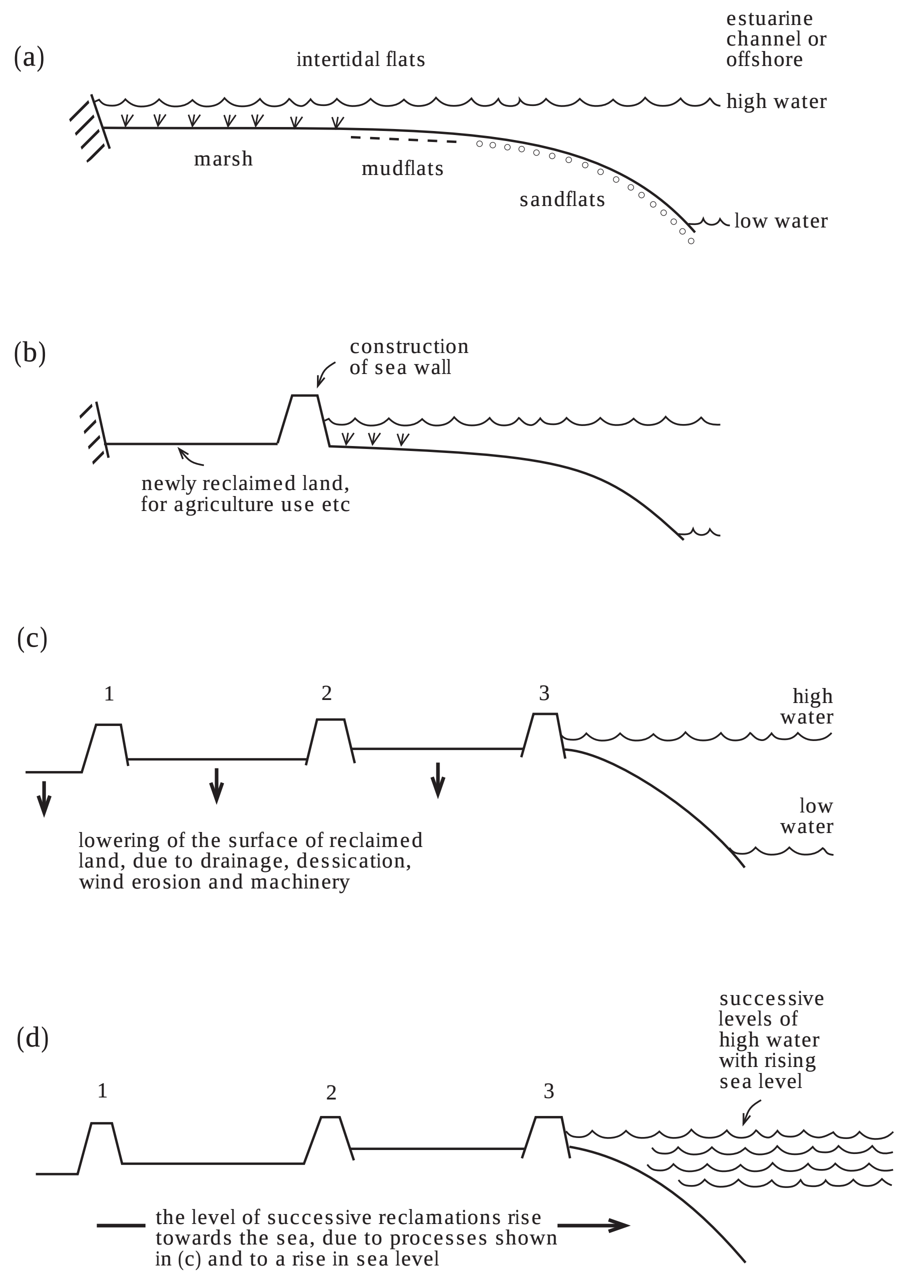

Fig. 8.- Reclaimed land: (a) a typical intertidal profile, (b) a typical reclamation, (c) lowering of the level of the land surface by man's activities, (d) the present situation caused by man's activities and rising sea level.

Fig. 8.- Ocupación de tierra: (a) un perfil intermareal típico, (b) una típica ocupación, (c) descenso del nivel de la superficie por actividades humanas, (d) situación actual debida a las actividades humanas y el ascenso del nivel marino.

Furthermore, this difference in level has been exacerbated by the Holocene rise in sea -level which, together with the subsidence caused, as explained above, has resulted in the un-enclosed salt marsh to seaward of the reclamations accreting to a higher level than the adjacent enclosed marshland. Consequently, where there has been successive enclosures over a long period of time, the surface elevations of these reclamations rise or "step-up" to seawards with the oldest having the lowest elevation (Fig.8 d). Thus enclosed lands have become very vulnerable to marine flooding when, during extreme events, the sea overtops the outer sea -wall. This occurred in 1953, during the Great North Sea Flood, when there was an enormous amount of destruction and loss of human life around the margins of the North Sea (Gerritsen, 2005; Baxter, 2005).

In addition, the presence of an artificial boundary (i.e. the sea wall) on the inner edge of the intertidal areas prevents the landward migration of the coastal salt marshes, which would occur under natural conditions, as the coastal lowlands are drowned during rising sea-levels. They thus become narrower and narrower and may disappear completely or remain merely as a narrow fringe. The subsequent loss of this rich natural habitat is already evident in some areas e.g. Essex U.K. The rise of sea- level, together with the increased frequency of storms, has resulted in the sea- walls suffering increased erosion. National and local authorities have become reluctant to continue to finance the maintenance of sea defences. Consequently, trials are taking place in some coastal areas, with the important acceptance that not all coastal lands can be preserved and that some land will have to be sacrificed under the in-

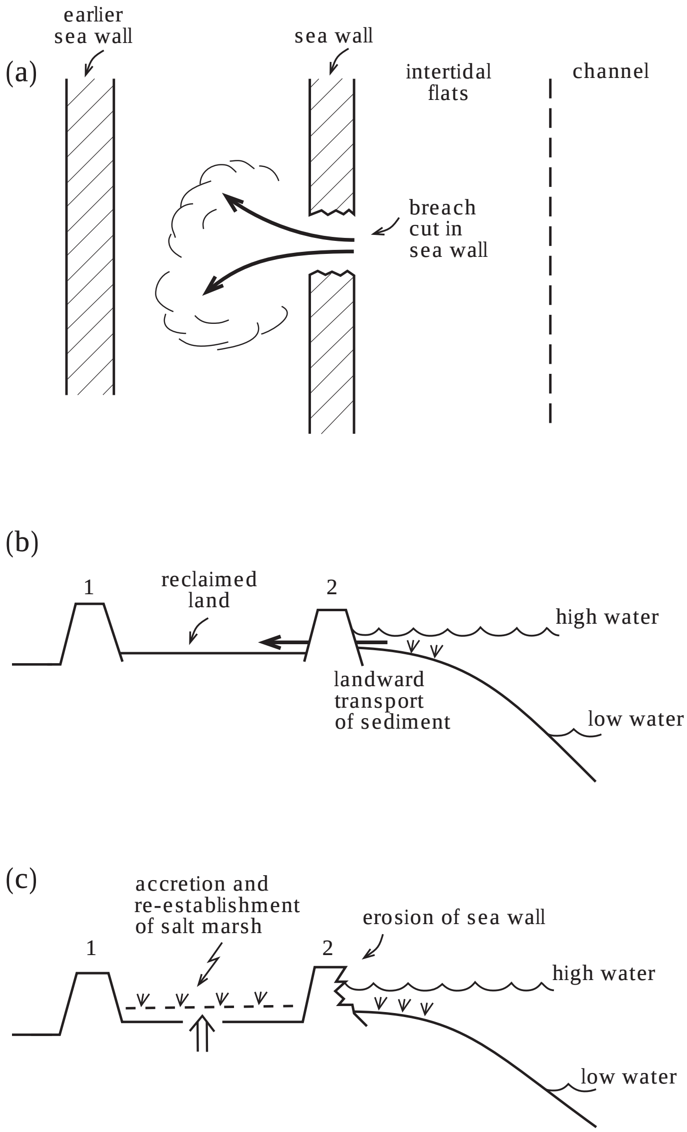

Fig. 9.- Managed Alignment: (a) typical breach in the sea-wall, (b) incursion of seawater and sediment, (c) the consequences of the breach.

Fig. 9.- Alineamiento intervenido: (a) rotura típica en el rompeolas, (b) incursión de sedimento y agua marina, (c) consecuencias de la rotura.

creasing stress of rising sea -level (Symonds and Collins, 2004). Such a scheme, termed "Managed Realignament", includes breaching the most seaward wall to allow the sea to reoccupy the enclosed land of the outer enclosure (Fig. 9a and b). This approach, it is hoped, will allow sediment carried into the outer enclosure to produce accretion of the surface to the level of the contemporary salt marshes to seaward; this will result in recolonization by salt marsh plants. In this way, the outer abandoned reclamation will help to dissipate wave energy and will provide at least a temporary protection for the often wide (> 10's kms.) enclosed lands to landward, by slowing down the effects of sea- level rise. Such a process, of course, will undoubtedly have to be repeated in the future as sea-level continues to rise.

Whereas these schemes lead to a loss of valuable agricultural land, there is a restoration of the intertidal habitats for indigenous faunas and floras. Hence the long-lasting practice of reclaiming land from the sea seems to be destined to be reversed in many areas. Instead, there is a policy to preserve wetlands. In many countries e.g. The Netherlands, the intertidal areas are now utilized as fish-hatcheries or fish- farms rather than for agriculture and in parts of England they are being used as wildlife sanctuaries e.g. Frieston Shore, Lincolnshire, U.K.

6. Deltas

Deltas are one of the most spectacular coastal landforms. They form extensive coastal protusions into the sea, where rivers supply such large volumes of sediment that these cannot be dispersed by the local marine processes; consequently the shoreline progrades seawards (Fig.10a).

The surface coastal plains of deltas are fertile and have been sites of civilization since early historical times, e.g. on the Tigris-Euphrates delta in Iraq, the Indus delta, Pakistan and on the Nile delta, Egypt.

Rivers supply water, sediment and nutrients to the delta and the adjacent marine waters. The prograding pile of sediments is deposited rapidly; thus it contains a considerable initial water content which is gradually expelled as the sediment compacts. However, the inflowing rivers, under natural conditions, maintain the surface levels of the coastal plain marshes and swamps by frequent flooding of the surface.

The supply of fresh sediment during floods enriches the surface soil where it has been cultivated and refills any man-made excavations e.g. such as those where clay has been excavated for bricks on the Nile delta (Fig.10a).

Nearshore waves and currents spread sand and gravel of the river load along the shoreline and allow the maintenance and growth of beaches and dunes around their coastal margins. The supply of river- borne nutrients to the adjacent waters supports abundant fish and other marine organisms and are the sites of important fishing industries (Fig.10a). Deltas are dynamic environments which are very vulnerable to interference by man. They are greatly affected by changes in the hinterland which alter the supply of water, sediment and nutrients. These are mainly caused by dam construction and the exploitation of raw materials (see later) (Fig10b).

Where the delta surfaces of the world have become colonized by man, the natural levees bordering the main channels have been raised to prevent flooding of the adjacent

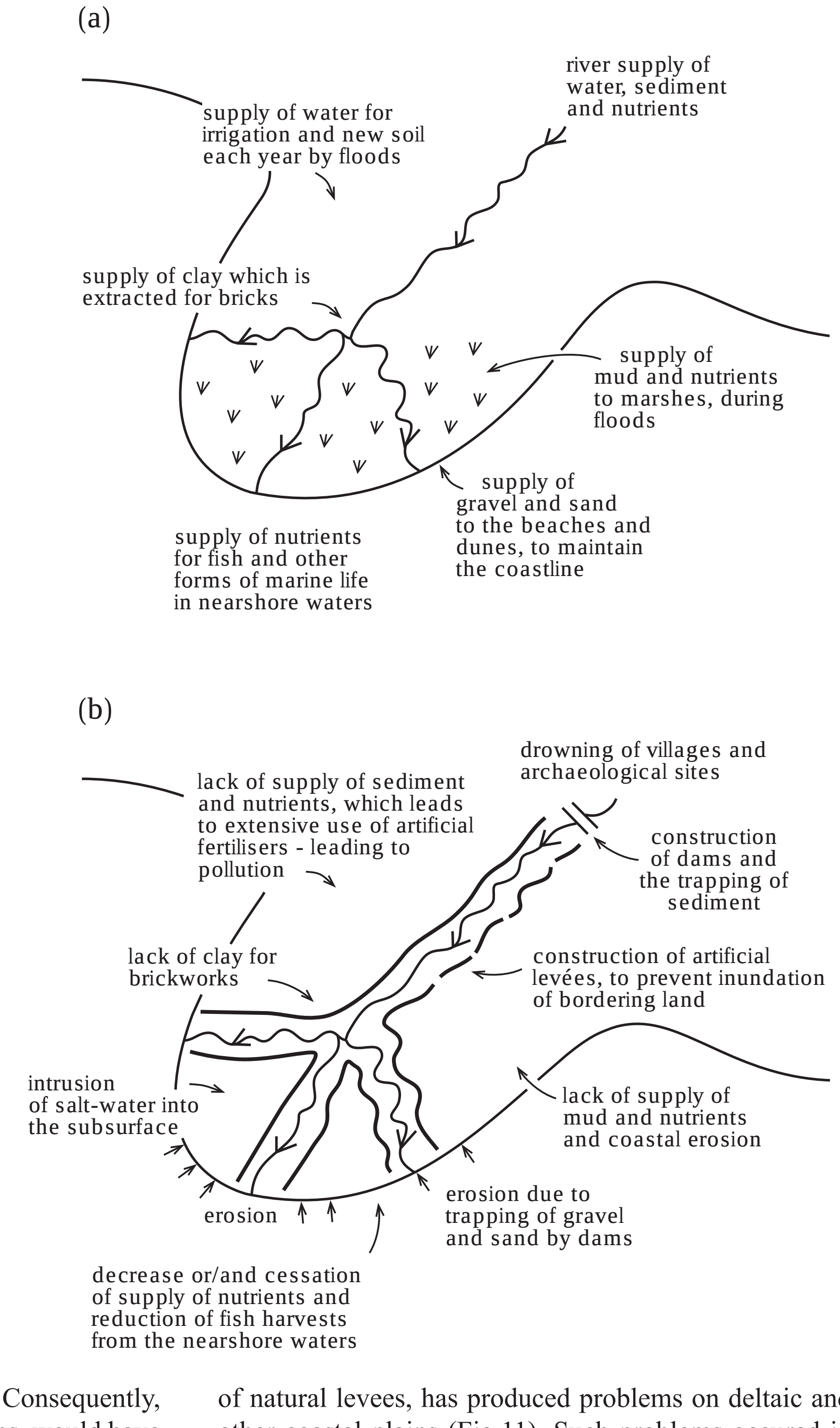

Fig. 10.- Deltas: (a) natural conditions, (b) examples of man's activities and their results.
Fig. 10.- Deltas: (a) condiciones naturales, (b) actividades humanas y sus resultados.

agricultural lands and human settlements. Consequently, the sediment which under natural conditions, would have escaped into the surrounding plains, has become trapped in the channels. Such a process raises their beds, and as the adjacent areas are still compacting, the effect of the natural lowering of the surface is exacerbated and thus prone to catastrophic flooding when the rivers ultimately break their banks during period of high discharge. This canalisation of river courses, to prevent the inundation of the adjacent land and settlements by raising the level of natural levees, has produced problems on deltaic and other coastal plains (Fig.11). Such problems occured in New Orleans, Louisiana, U.S.A. during and after Hurricane Katrina.

Drainage of the surrounding lowland between the various distributaries has led to further compaction of the underlying sediments. Where the soil is rich in organic matter or is a pure peat this is rapidly broken down by oxidation. The relatively dry surface of such very light soils is prone to wind erosion and is sometimes formed

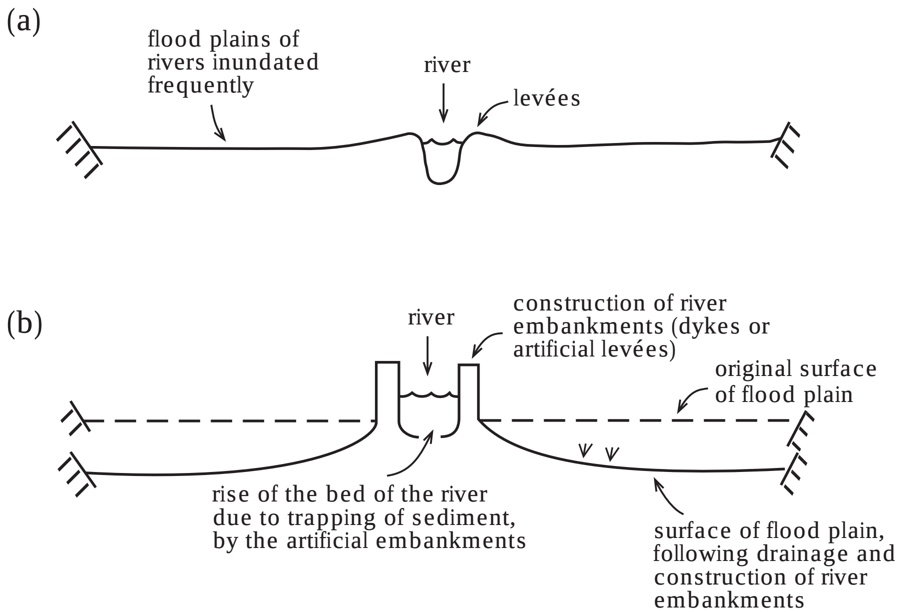

Fig. 11.- Trained river channels: (a) natural situation on a fluvial plain, (b) the consequences of training works.

Fig. 11.- Río y canales encauzados: (a) condiciones naturales en una llanura fluvial, (b) consecuencia de los trabajos de encauzamiento.

into small aeolian dune fields e.g. Fenland, UK.

The net result is that, for example in part of the English Fenland, the ground levels have fallen by 3.8 m between 1848-1957; this is still continuing at a rate of approximately 1.4 cm/yr (Fowler, 1933; Fillenham, 1963; Richardson and Smith, 1977) (Fig.12).

Also, the lack of an annual supply of new sediment together with associated nutrients, has led to the need for more use of artificial fertilizers by the agricultural industry; this in turn has lead to pollution of drainage ditches and lagoons into which they drain.

Natural marshes are also starved of river- borne nutrients and deteriorate, e.g. there is widespread erosion of marshes around the Mississippi delta. Brick -making industries on the Nile delta have suffered due to the cessation of the annual supply of clay and silt; this was provided normally during floods to replace the excavated material. This has led to the enlargement of local brickpits on the Nile delta to compensate for the lack of infilling sediment and the subsequent loss of agricultural land, a practice now forbidden by the Egyptian government (Lee, 1983).

The constriction of flow by the construction of raised levees has also led to changes at the river or distributary mouths. The canalisation of the river flow has changed the morphology of many deltas. The birdfoot pattern of the modern Mississippi delta, which is so different from that of earlier Mississippi sub-deltas, has been exacerbated or may have been largely produced by such changes (see Walker and Davis, 2002) for a modern discussion of engineering work on the Mississippi). The rate of progradation of some deltas has been increased by the confining of the river flow, e.g. the rate of progradation of the Yellow river has been increased historically by such changes

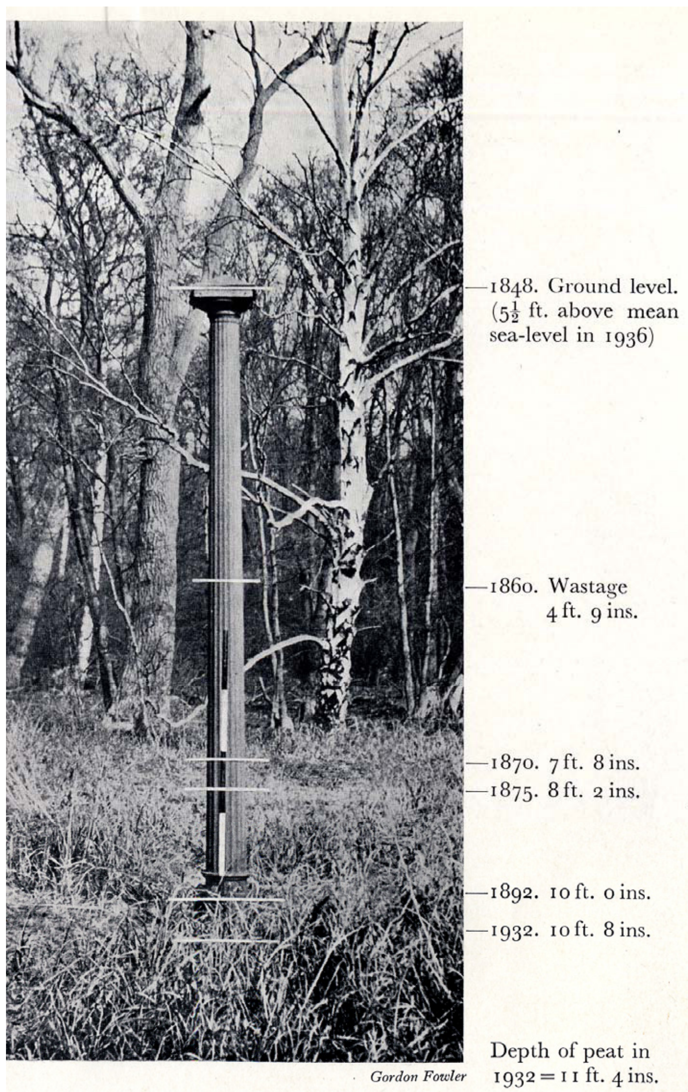

Fig. 12.- Subsidence of coastal lowlands: an example from the Fenland, UK.

Fig. 12.- Subsidencia de zonas costeras bajas: ejemplo de Fenland, UK.

(Jiongxin Xu, 1993). The exploitation of gas and oil in some deltas, such as the Mississippi and Niger, has necessitated the cutting of new channels to provide access for drilling rigs; this, in turn, has resulted in erosion and further destruction of natural marshlands by wave erosion induced by the passage of fast boats.

The lack of supply of sediment to the coast, because of dam construction inland, has led to widespread erosion on many deltas of the world. This has been increased by the continued compaction of the sediment and the rise in sea- level producing marked coastal retreat e.g. The Nile (Stanley and Warne, 1993). Also the likelihood of salt water intrusion to coastal aquifers has increased.

7. River Diversion, Coastal Displacement and other miscellaneous human impacts

The diversion or extensive utilization of river water, as well as the construction of dams, have had a dramatic impact on some coastlines. For example, the large scale use of water for the irrigation of cotton from the Amudarya and Syrdarya rivers flowing into the Aral Sea, Central Asia, and the diversion of the waters of the Karakum canal into the Turkmenistan desert, has led to the shrinking of the Aral Sea. The sea- level fell by > 20 m over a period of 40 years; consequently parts of the coast have receeded seawards by as much as 75 km. This has led to the World Bank awarding \$45 x 10^6 to alleviate the socio-economic problems of coastal communities (Glantz, 1999; Waltham and Sholji, 2001; Gill, 2000).

A similar proposal in Spain, to divert part of the discharge of the Ebro by constructing a canal from Cherta to Almeria, has caused much consternation to those responsible for preservation of the Ebro delta (Burgen, 2002). Fortunately, this project has now been abandoned, but it could be reactivated in the future (A. Arche, personal communication).

On some occasions, man has deliberately drowned low-lying coastal plains in some areas to hinder forces invading from the sea. China drowned parts of the eastern coastal plains in an attempt to slow the advance of the invading Japanese armies in the 1930s. Also, the German army drowned the coastal plains of Holland and the marshes behind the beach-dune barriers of western France in an attempt to impede the Allied invaders in 1944 (Rose and Pareyn, 1995, 2003). Sometimes, beaches were disturbed and altered during landing exercises for the Allied invasion of Normandy in World War II; such in Amroth, Pembrokeshire south western Wales (Howells, 2003; and R. Howells, personal communication).

Recently, man's thoughtless interference has resulted in increased damage to coastlines when they have been struck by tsunamis. The impact of the 2004 tsunami in Sri-Lanka was exacerbated by the clearing of dunes in some areas, merely to allow guests in local hotels to get a better sea view. Also, the mining of the protective rim of coral-reefs made parts of the adjacent coastline more prone to erosion when the tsunami struck the island. In addition, interference of the local mangrove thickets led to the adjacent areas suffering increased damage (Gunatilaka, 2007 in press; and A. Gunatilaka, personal communication). One of the unfortunate consequences of the extensive use of beaches by humans is the presence of litter along coastlines e.g. many of the beaches in the Arabian Gulf are covered with mounds of plastic and other human debris (personal observation). Also the practise of discarding rubbish from ships at sea is adding to this problem and is likely to increase. It has been estimated that approximately 2000 pieces of plastic despoil every square kilometre of the floor of the Mediterranean Sea and if this is mobilized by the predicted more violent storm conditions it is likely to be deposited on the surrounding beaches, (Nash, 2007). Many countries still pump large volumes of human sewage into the adjacent seas. This still occurs in some advanced countries, e.g. the sewage from 250,000 inhabitants around Brighton, U.K. is poured from an outlet which is merely 2 km offshore. This material is sometimes washed onto the adjacent beaches (Grimston, 2007).

8. Extraction of Groundwater, Oil, Gas and Peat, etc.

The extraction of fluids from sediments of the coastal plains have lowered ground surface levels and made them more prone to flooding (Fig.13a). Subsidence due to groundwater extraction in Bangkok was >7 cm/yr in some areas with a total subsidence between 1978—1987 ranging from 30-75 cm (Nutalaya *et al.*, 1986).

Also, in Shanghai, China groundwater extraction between the late 1950´s-1970´s caused subsidence >10 cm/yr.; however this has been reduced by restrictions in ground-water extraction (J.Y Chen: oral communication to J.D. Milliman, in Milliman, 1997).

Similarly, subsidence has been produced in this way on parts of the Japanese coast (Jelgersma, 1996, in other East Asiatic cities (Milliman and Haq, 1996) and in parts of the USA, such as in the Galveston and Houston areas of the Gulf coast (Jelgersma, 1996).Perhaps more famously, this process has occured in Venice, Italy, where natural subsidence of this deltaic area (Barbieri *et al.*, 2007) has been greatly increased by the extraction of water to supply the Marghera industrial complex which commenced in 1920. Even after the excessive pumping ceased in 1970 and there was a slight recovery of ground levels

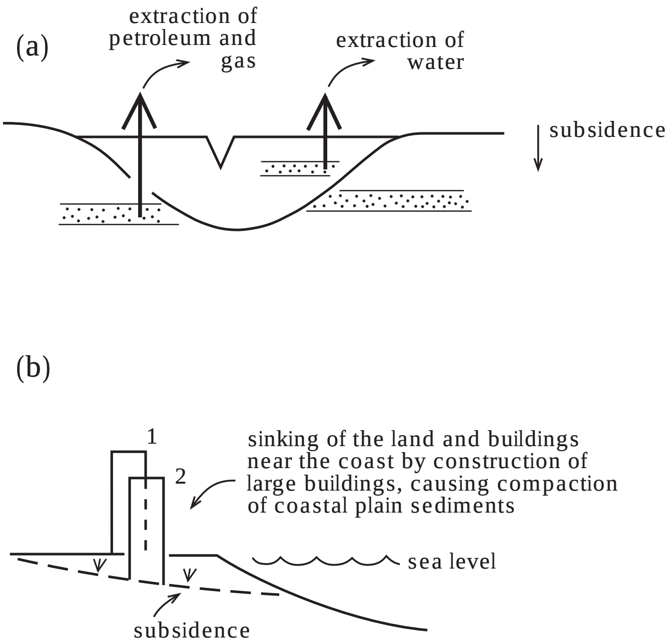

Fig. 13.- Lowering of the surface of coastal lowlands by: (a) the extraction of liquids and gas, (b) the construction of large buildings.
Fig. 13.- Descenso de la superficie en zonas costeras bajas debido a: (a) extracción de líquidos y gas, (b) construcción de grandes edificaciones.

there continues to be a gradual subsidence (Cabognin and Cecconi, 1997).

The extraction of oil from the Wilmington oilfield beneath Long Beach Harbour, Los Angeles, USA, produced subsidence; this was partly relieved when water was injected into the reservoirs to improve oil recovery (Barrends *et al.*, 1995; Waltham 1989, 2002). The loading of the surface of water- bearing coastal -plain sediments by buildings, e.g. the evidence of sinking and leaning churches in the Fenland of eastern England, has lowered the surface and has made them more prone to flooding (Waltham, 1989) (Fig.13b). Loading by dumping of landfill has caused similar subsidence e.g. dumping of fill on soft sediments, for the construction of La Guardia airport, New York, USA, led to the land sinking 2.5 m over 25 years (Jelgersma, 1996).

Man has throughout history altered coastal plains by the large scale surface extraction of clay, sands, peats, etc for building materials and fuels. This has often left large depressions which become infilled with water because of the closeness of the water table to the surface. Locally generated waves produce erosion along the margins of these depressions and this has caused their enlargement; sometimes the merging of adjacent depressions has produced large areas of open water. Subsequent coastal retreat and the breaching of coastal barriers, under rising sea level, often result in such features being drowned by marine waters (Fig.14) e.g. the Norfolk Broads on the eastern coast of England,is a large area of linked estuaries, coastal lakes and lagoons which was produced in this way. Extensive Medieval peat-digging left a series of large excavations in the floodplains of the local rivers. These were subsequently enlarged by local wave erosion and have been filled with freshwater and by marine water in their outer parts during the Holocene rise in sea- level. Today, the Norfolk Broads is an extensive area of sheltered coastal water bodies which pass into an intricate pattern of creeks flooded and drained by the tides (Lambert *et al.*, 1960).Today, the area has a flourishing tourist industry, where many can enjoy the pleasure of boating in relatively safe and sheltered waters. Hence at this location, medieval Man´s activities combined with rising sealevel, have created a socio-economic (tourism, boat-hire etc.) benefit to the surrounding area. However, the natural wildlife of the area has suffered because of the diminution of the area of natural habitats and the intrusion of large numbers of people during summertime.

9. The Hinterland

Man's activities in the hinterland have a great effect on the adjacent coasts (Fig.15a). It has been claimed that today humans have a greater effect than natural processes on the Earth´s surface, with the mean rates of erosion of croplands exceeding the rates of soil formation by an order of magnitude (Wilkinson, 2005). Land clearance, mainly for agricultural purposes, has been on an immense scale e.g. in the USA, 80,937,100 hectares of land was cleared between the early years of colonization during the XVI Century and the 1920s (Conzen, 1980).These activities have increased sediment run-off (Fig.15b). For example, data collected by Dedkov and Mozzherin (1992) suggest that 75% of the present sediment yield of the Mediterranean river basins is attributable to human activity (Woodward, 1995). Contrary to earlier views, such activities have occurred over long periods of human history. In the North of Spain the protection of land by Visigoth kings disappeared following the Muslim invasion of the XIII Century when land was cleared for refugees. Sheep owners (The Meseta Council) obtained rights to clear land and graze areas and these persisted until the XIX Century. Also, there was widespread clearing of forest for shipbuilding, charcoal and the production of fuel for armament factories in the XVII- XIX Century as well as forest clearing for the planting of new exotic species such as *Eucalyptus*. All these changes have produced an increased discharge of sediment in the rivers (Adedo *et al.*, 1990; Bauer, 1980; Ceballos and Ortuno,1997). Elsewhere it is now clear that deforestation in parts of Greece

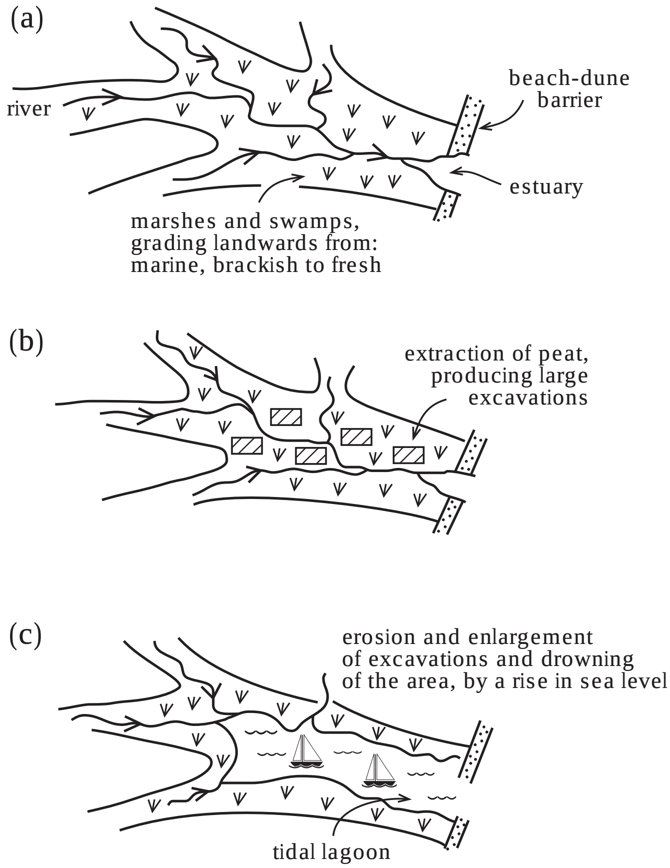

Fig. 14.- Evolution of The Norfolk Broads, UK.: (a) the original natural state, (b) medieval peat diggings, (c) the present situation, following the rise of sea-level, drowning of the diggings and their enlargement by wave erosion.

Fig. 14.- Evolución de The Norfolk Broads, UK: (a) condiciones naturales, (b) excavaciones medievales de turba, (c) situación actual tras el ascenso del nivel marino, la inundación de las excavaciones y su ampliación por erosión costera.

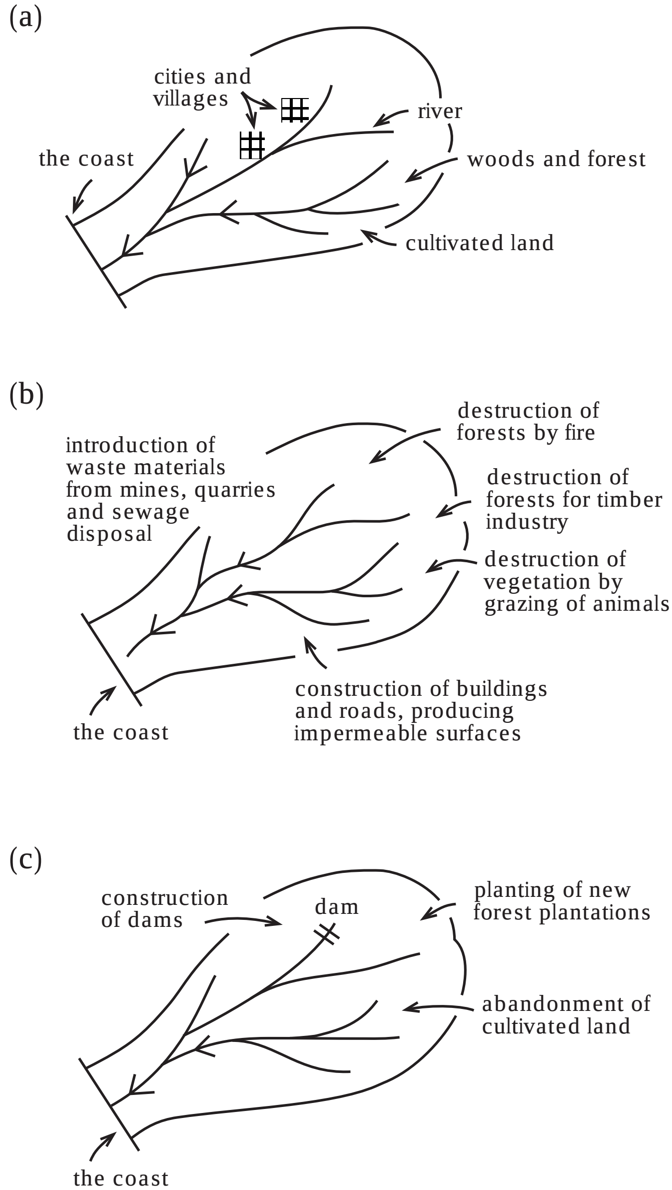

Fig. 15.- The hinterland showing : (a) a typical developing river basin, (b) man's activities, which increase the sediment supply to the coast, (c) man's activities, which decrease the sediment supply to the coast.

Fig. 15.- La zona continental interior muestra: (a) una típica cuenca fluvial en desarrollo, (b) actividades humanas que incrementan el aporte sedimentario a la costa, (c) actividades humanas que disminuyen el aporte sedimentario a la costa.

occurred very early and has continued over the last 8.000 years (van Andel and Runnels, 1987; van Andel *et al.*, 1990; Runnels, 1995). Overgrazing mainly by goats, and the clearance of forest in Anatolia have led to an increase in sediment yields throughout history. Already in Classical Times problems occurred in the ancient ports due to siltation (Eisma, 1978; Bruckner, 1997). The run-off of sediment often fluctuated as the readily transportable sediment was carried away, and then levelled off, as the hinterland was stripped bare of soil; this in turn led to pulsating growth of the coastal deltas (Eisma, 1962).

As well as the increase of sediment loads produced by land clearance, the widespread use of plastic to cover crops and other agricultural developments, there have been increases produced by the development of large cities. This has resulted in the cutting of new roadways, building construction and the huge increase in hard surfaces all of which have prevented the infiltration of rainwater (Wolman, 1967; Walling and Gregory, 1970; Costa, 1975; Wolman and Senick, 1987).

In contrast to the increase in sediment run-off to the coastlines, the reverse has occurred in more recent times in some areas by the widespread construction of dams which have undoubtedly brought many advantages to local communities (Fig.15c).

Approximately one third of the irrigated land in the world is dependent upon dams for its water supply, whilst one third of the countries of the world depend upon them for at least half of their electrical power (Anon., Economist, Nov. 18, 2000). In addition, dam construction has allowed the development of large inland fishing industries where none existed previously.

However, in spite of the obvious advantages to the population in various parts of the world, it has been gradually realized that there are serious consequences of dam construction; this is, in spite of the fact that over the years >$2 billion have been invested in them. A recent analysis by the World Commission on Dams of the economic consequences of large dams have seriously questioned the supposed benefits of their construction on the major rivers of the world (Shewstack, 2000).

Local loading of the Earth´s crust, by the impounding of water behind dams, has been found to trigger faults movements and local earthquakes (Nikonov, 1977).Further problems can occur where dams are poorly sited, constructed and maintained in some third world countries e.g. there is great concern about the Saddam Dam, north of Mosul, Iraq, which is in danger of collapse; this would produce devastating floods downstream in the Tigris valley (Cockburn, 2007). Also, the creation of large water bodies has caused the spread of water-borne diseases in inland Egypt where these were previously unknown; rotting vegetation has added to global warming; water released from dams affect water properties downstream and fish and animal populations (Anon., Economist, 2000; Schwarz, 1985). Dam construction has necessitated widespread displacement of local populations; the Three Gorges Dam in China has caused the displacement of millions of people. Also, the drowning of famous archaeological sites, some of which have hardly been investigated, has caused widespread protests.

The construction of dams, in many parts of the world, have produced a drastic reduction in the supply of sediment to the coastline. Meade and Trimble (1974) showed that there was a decline in the suspended load of the east coast rivers of the USA between 1910-1970 due to dams and changing land usage. The effective areas of river catchments as sources of sediment have been reduced by 70% in West Africa; this has had repercussions on the coastline where there is widespread erosion (Collins and Evans, 1986; Bourke, 1987), with erosion on the Niger delta reaching up to 20-30 m/yr (Ibe, 1988). The construction of a dam on the Seyhan river, Turkey in 1954 has resulted in 1,012,536 m^2 of sediment being eroded from around the river mouth. Subsequent dam construction on the neighbouring Ceyan river has caused a marked decrease in delta- growth and erosion in some places since 1984. Similar erosion on the neighbouring Goksu delta is likely to occur if the proposed plans for damming are carried out (Cetin *et al.*, 1999). Since the completion of the Aswan Dam in 1971, which is located 1000 km from the coast, there has been widespread erosion of the sandy shoreline at the mouths of the distributaries of the Nile of 143-160 m/yr. Also, the breakdown of the barrier islands linking the various distributary mouths of the Nile has been accompanied by the loss of valuable fish harvests and the traditional fishing nurseries in the lagoons, as well as a drastic drop of fish catches in the offshore because of the decrease of nutrient supply (Sestini, 1976, 1992; Sharaf el Din, 1977; Inman and Jenkins, 1984; Abdel-Aal,1985 and El Sayeed, 1996). Similarly, on the Ebro river, Spain, the construction of dams has led to < 10% of the former river sediment (i.e. that prior to the dam construction) reaching the coast and erosion now dominates the shoreline (Guillén and Palanques, 1992, 1997; Jiménez *et al.*, 1997).

The Mediterranean coastline has been affected greatly by the damming of rivers over many centuries. The Romans built dams in Libya, which soon became infilled with sediments, particularly after the Muslim invasions, or were abandoned (Vita-Finzi, 1969). Today, the Mediterranean rivers have 3,500 dams along their courses, 98% of which were constructed since 19th Century (Woodward, 1995; Poulos and Collins, 2002). Not only have coastlines eroded and offshore fisheries declined because of the reduction of, or lack of, nutrients, but it has also been claimed because of the massive reduction in the discharge of freshwater, that the salinity of the sea has increased and the increased outflow of its waters has even affected the Atlantic Oceanic circulation (McKie, 1997). Elsewhere dam construction on the Yellow River, China, is likely to ultimately reduce the river load to the adjacent sea by 30-40% in the early 21st Century (Ren and Xianmo, 1994). Nevertheless, there are still plans to build more dams (Pearce, 1991); in spite of the World Commission on Dams' conclusion that they generally have a negative impact on the world's ecosystem (Anon. Economist, 2000; Schwarz, 1985), as well as the widespread unease among scientists about dam construction (Schwarz, 1985; Lee and Bullock, 1990; Anon. Times July, 13, 2000; Juniper, 2000 and Morgan, 2000). For example there are still plans to dam the Mekong, Vietnam, and this is causing much concern about the likely affect on the coastline and the fisheries, which are the sole means of support for approximately 1x 10^6 people (Anon., Economist, 2004; McGirk and Buncombe, 2005). Furthermore there has been much public protest over the Sarover dam and its effect on the coastal- plain communities of Gujarat, India, (Popham, 2001). However, fortunately, but only occasionally, protests alter and sometimes delay construction to enable the completion of archaeological studies of interesting sites.

This occured in Turkey, where the famous ancient city of Zengma on the Euphrates, is likely to be soon sub-

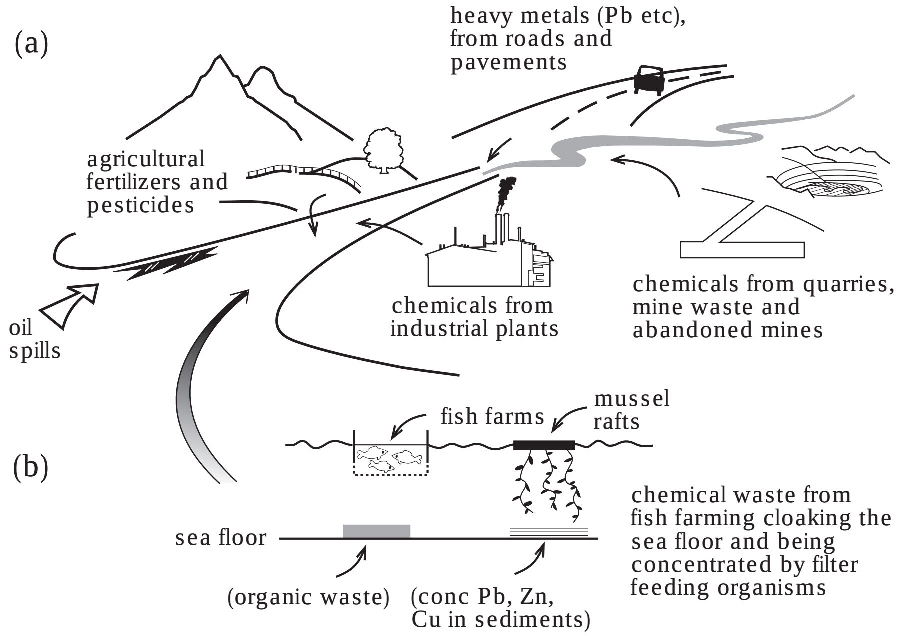

Fig. 16.- Common sources of chemical pollution of the coast.
Fig. 16.- Fuentes habituales de contaminación química en la costa.

merged by the planned construction of the Birecik dam (Finkel, 2000).

Dam construction in areas of limited water supply also produce enormous political tensions (Pearce, 1992). The large Kemal dam -project on the Euphrates in Turkey will affect Syria and Iraq and the proposed dam on the Yarmuk river in Syria and Jordan will have repercussions for Israel (Richards, 1990; Lee and Bullock, 1990).

Fire, either accidental, or produced deliberately by man, is another phenomenon which increases the sediment run-off by the removal of the protective cover of vegetation. Increased sediment yields are sometimes as much as a thousand-fold in Australia after such events (Pereira, 1973).

Forest fires have occurred frequently in Spain in the 25 years leading up to 1982, 871,248 hectares of land were affected in Galicia, i.e. they affected 45% of the uncultivated land (Diaz-Fierros *et al.*, 1982). Such fires are particularly common in areas surrounding the Mediterranean (see references in Sala *et al.*, 1991; Sala *et al.*, 1994). Ash, originating from such fires, coated the beaches of Galicia in the summer of 2006, and also contaminated the local shellfish (Anon., El País, 2006; Rivas, 2006; Nash, 2006).

10. Offshore dredging

Not only do changes in the hinterland have an impact on the coastline, but also those produced by man in the adjacent marine areas. The dredging of offshore sandbanks, which under natural conditions filter out the energy of large waves, can expose the adjacent coast to erosion.

Today, dredging of offshore sand and gravel is a multi-billion dollar industry and its effects are likely to be considerable in the long term, even if these are largely unknown. There is still, in some areas, only a sketchy understanding of the dynamic links between offshore sandbanks and the adjacent coastline. Although, elsewhere, it has been established to the satisfaction of local authorities that these can be safely dredged. The planned extraction of sand and gravel from the eastern parts of the English Channel, for the building of the stadia for the Olympic Games to be held in 2012 in London, is already causing disquiet in some scientific circles as this could, ultimately, have serious repercussions on the adjacent coastline.

11.Chemical pollution

The movement of populations to the coast and the development of industries, on both the coast and in the drainage basins of the rivers, have led to widespread pollution of coastal environments (Fig.16). Estuaries, in particular, are often highly polluted along many of the world's coastlines, e.g., intensive industrial development in the Basque Country, Northern Spain, over the last two centuries has made the Bilbao estuary one of the most polluted in Spain. However, economic recession has reduced significantly the input of noxious material into the estuary and a programme has been initiated to alleviate the situation (Cearreta *et al.*, 2000). The dumping of mine waste from local phosphate mining has produced cadmium pollution in the Samlice estuary, North Carolina, USA (Cooper, 1999). Elsewhere, accidental spills have introduced vast quantities of industrial mine waste into some estuaries. In 1998, the bursting of a mine -dam in Spain led to the release of millions of cubic meters of pyrite sludge and other concentrates, this rapidly reached the Guadiamar river, but fortunately did not reach the Doñana Nature Reserve but was instead directed into the Gulf of Cadiz (Ruiz, 2001; García-Luque *et al.*, 2003; Nagel and Lang, 2003; Olias *et al.*, 2005). The increase in population and industrial activity since the 1960´s as well as the development of coastal fisheries (e.g. the installation of *Mytilus* sp. rafts) has led to an increase in heavy metals in the bottom sediments of the rias of Galicia (Cobelo García *et al.*, 2004; Collazo *et al.*, 1997; Evans *et al.*, 2003; Howarth *et al.*, 2005).

Lagoons are particularly prone to pollution due to their restricted circulation (Bartoletti *et al.*, 1985). For example the Manzala Lagoon, Egypt, has been polluted by urban waste from Cairo (Halim and Gerges, 1981). Heavy metals (Zn, Pb, Cu and Cd) have been concentrated in the lagoon sediments of Lake Macquarie in southeastern Australia from a local smelting plant (Roy and Crawford, 1984). Human and industrial waste has polluted the famous Venice lagoon where the normal tidal flushing by Adriatic waters is not sufficient to prevent the contamination of the sediments (Zuchetta, 1983; Cossu *et al.*, 1987; Cabognin and Cecconi, 1997; Ravera, 2000).

Heavy metals can often be dispersed alongshore by wave- induced currents and tidal currents to pollute areas far from their original source (Nicolaidou and Nott, 1998; Li *et al.*, 2001; Tanner *et al.*, 2000), or even be carried into other estuaries (Williams and Milward, 1998). The dumping of military waste has been a source of pollution in other areas (Miller *et al.*, 2000).

Leakage of petroleum from shipwrecks, ship collisions and military action has produced dramatic pollution of extensive reaches of the coastline; in some areas this has led to severe problems for coastal communities, the fishing industry and local tourism (White, 2005). Numerous oil spills (56) have occurred around the coast of Iberia since 1950; the most recent being that of the Prestige in November 2002, when 63,700 tons of the cargo was released into the sea; there it was widely dispersed to foul beaches and to ruin coastal fisheries on the northern coast of Spain, as well as extending much further afield (González *et al.*, 2005a and b; IOPC, 2003; Stein, 2003).

The bombing of oil wells and oil terminals in the Gulf War (1991) led to oil spreading from Kuwait along the western shorelines of the Arabian Gulf (Literathy, 1993; Gerges, 1993). Recently, the Israeli bombing of the Jiyyeh power station, south of Beirut, Lebanon, produced oil slicks which were carried northwards to pollute the beaches of Lebanon and Syria and were predicted to reach the coast of Turkey (Anon., Geographical, 2006).

12. The Future

What of the future (Fig.17)? Generally, scientific opinion accepts that global warming is causing a rise in sea level (Heckstra, 1988; IPCC, 2007). This is likely to result in increased coastal erosion, increased landward migration of beach-dune coastal barriers, increased intrusion of water and sediment into estuaries and the increased penetration of sea water into the sub-surface sediments of coastal lowlands to pollute aquifers in some countries e.g. Greece (Poulos *et al.*, 2007). At the same time the movements of population to the coastal zone is bringing many problems. Already, overpopulation of this zone in Israel has caused over- abstraction of water and thus has increased the salinity of the coastal aquifers (Lee and Bullock, 1990).

These changes in sea -level will have a marked impact on small, low and densely populated mid-oceanic islands. Together with the shortsighted destruction of the protective reefs, for building materials, and the dynamiting of these during fishing, it is likely to lead to their complete disappearance (Boehm, 2006).

Recent oceanographic studies (Hoff, 1994; Lynagh, 1997) indicate that the wave climate in the North-east Atlantic has become more severe in recent decades paralleling the increase of deep low-pressure systems in the area. This is likely to impact on the coastline, thus causing increased coastal erosion; this together with increased current strengths will lead to the mobilization of more sediment and possibly its intrusion into estuaries and lagoons.

Increased storm strengths are likely to bring increased dangers to cities on coastal plains. The lowering of surface levels produced by the construction of large buildings, the prevention of sediment dispersal from the rivers, drainage and the resulting sediment compaction all have increased their vulnerability. This has recently been dramatically illustrated by the tragedy which accompanied Hurricane Katrina´s destruction of large areas of New Orleans, USA, in August, 2005 (Fischetti, 2005a and b; Waltham, 2005; Nelson and Leclair, 2006; Grunwald, 2007). The introduction of "soft engineering" is an attempt to solve the local problems of coastal erosion, by not merely building higher and larger coastal defences; although the latter will still be necessary to protect some areas of large cities and important industrial complexes situated on the coastline, at least, in the immediate future.

The widespread loss of coastal wetlands, due to the industry of man in the conversion of these into fertile agricultural land for the production of cash crops, appears to be ending. There are of course exceptions e.g. the draining of the coastal marshes of Iraq. Here 20,000 km^2 of the former marshland were drained recently (Lubick,

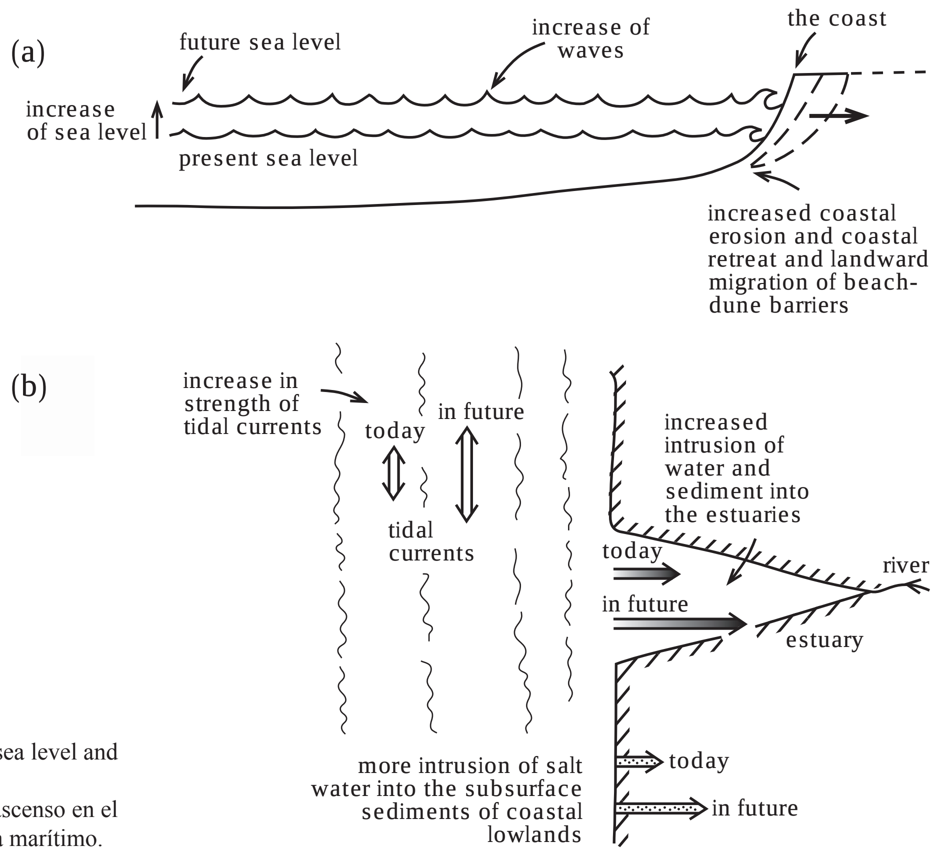

Fig. 17.- Likely future effects of rising sea level and a changing marine climate.
Fig. 17.- Probables efectos futuros del ascenso en el nivel marino y del cambio en el clima marítimo.

2003). However, this was undertaken partly for strategic rather than commercial reasons. Already an attempt is being made to restore this unique area of marshland and lagoons to its former state (Sultan *et al.*, 2003; Glanz, 2005). Also, a large reclamation of wetland has recently been completed in South Korea, which will deprive 400,000 migrating birds of a resting place during their annual migration between South East Asia and the Southern Hemisphere (Connor, 2007).

In recognition of the importance of deleterious effects of changes in the hinterland in controlling sediment fluxes to the coast and on fisheries, some dams have already been destroyed in the USA. The Elwa and Gliaes dams are two of some of those intentionally destroyed (Anon. Geotimes, 2000). These dams, constructed in 1927, had reduced salmon movements from 380,000 to 3,000 in the 1990s and reduced the flow of sediment to the delta on the Pacific coast, which will now be restored. Vast sums have been spent in the USA, e.g. in Washington State, to attempt to return rivers to their natural state (Montgomery, 2004). However, in some parts of the world new large dams are still being planned, in spite of all the known problems (Pearce, 2006).

In various areas different responses to natural and economic pressures will alter the flux of sediment to the coast. Changes in climate in the hinterland, with more intense rainfall is likely to increase sediment run-off in some areas; whereas elsewhere increasing aridity may cause increased mobility of the surface sediment by wind.

In contrast, the changing patterns of agriculture, due to the overproduction of food is leading to the abandonment of former agricultural land which is no longer profitable to cultivate. This, in turn, will lead to the spread of natural vegetation and the decrease in sediment run-off and flooding. However, this recent trend may be reversed if, as appears likely, Man in the face of decreasing supplies of gas, coal and oil will attempt to replace them with biofuels. There is a growing body of research that suggests the abandonment of hill-farming and the planting of woodland is the sensible way to prevent run-off of sediment and flooding downstream (Anon., Economist, 2004). The growing awareness of the interrelationship between the hinterland and the coast and coastal processes will, it is hoped, result in greater sensitivity to the likely changes produced by Man´s activities in this important environment.

13. Conclusions

Man, in spite of his relatively short occupation, in geological terms, of the planet has had a disproportionate impact on the coastline by his activities in the hinterland and on the coast itself. Although the danger facing coastal communities has been repeatedly stressed by scientists, many governments and local authorities are reluctant to take necessary, but often costly and unpopular, remedial measures to coastal problems. Instead, they persist with conventional practices and remedies even when their efficacy is doubtful. Some local authorities even ignore advice from their national government if this is not politically expedient, e.g. several local authorities in the U.K. have refused to take advice from national research agencies not to build on river flood plains. It takes events, such as the recent destruction of New Orleans, USA, and the recent extensive flooding in the U.K. to persuade such authorities to take a more enlightened view. Even after such events they seem to balk at taking the most sensible remedial measures, if these are not seen as politically advantageous (Grunwald, 2007). It is difficult to be optimistic about the future, particularly as regards the future of the hinterland. Here the pressure for development (deforestation, dam construction etc.) created by the predicted large increase in populations and their demands for food, water and power is likely to be enormous. As pointed out by Elliot (2007), perhaps the scientists are using the wrong language. Governments and local authorities need to be, in the words of that writer: "grabbed by the wallets". Constanza *et al.*, (1997) argued powerfully of the economic importance of the world's ecosystems, including coastal areas and their hinterlands. They have warned that the neglect of these will ultimately threaten the continued existence of humans on this planet.

Acknowledgements

The author wishes to record his gratitude for the generous help of Manu Monge-Ganuzas who typed the manuscript; Rosemary Evans and Bartholomew Messervy Evans for ammending the manuscript; Alejandro Cearreta for translating the abstract and the description of the figures into Spanish; Kate Davis for producing the figures; Carl Leonatto Amos for help with the Italian literature; Alfredo Arche Miralles for help with the Spanish literature and Roscoe Howells for information on the southwestern coastline of Wales. Also, to thank The Independent newspaper for permission to reproduce the cartoon by Dave Brown and Blackwell Publishing Company, Oxford for permission to reproduce the photograph of Holme Post. The text has been improved by copious comments and suggestions kindly provided by Alfredo Arche Miralles and by Michael B.Collins.

References

Abdel-Aal, F.M. (1985): *Erosion of the Nile Delta coast. Proceedings Coastal Zone 85. American Society Civil Engineers*: 1601-1611.

Adedo, C., Diego, C. García-Codrón, J., Moreno, C. (1990): *El bosque en Cantabria*. Universidad de Cantabria. Biblioteca Básica 3: 286 p.

Andel, Tjeerd H. van and Runnel, C. (1987): *Beyond the Acropolis*. University Press, Stanford, California: 221 p.

Andel, Tjeerd H. van, Zanger, E., Demitrack, A. (1990): Land use and soil erosion in Prehistoric and Historical Greece. *Journal of Field Archaeology*, 17: 379-396.

Anon (2004): The sweet serpent of SE Asia. *The Economist*. January 3: 41-44.

Anon (2004): Flood Control: a good soaking. *The Economist*. October 23: 92.

Anon (2000): A barrage of criticism. *The Economist.* November 18: 156-157.

Anon (2000):Flowing Freely. *Geotimes*. October 11.

Anon (2000): Dam nonsense. *Times*. July 13.

Anon (2006): Oil spills in troubled waters. *Geographical*, 78: 8.

Anon (2006): Los expertos temen que las lluvias arrastren la ceniza a las rías y se contamine el marisco. *El País*, 15 agosto.

Barbieri, C., Di Giulo, A., Massari, E., Asioli, A., Bonato, M., Mancin, N. (2007): Natural subsidence of the Venice area during the last 60 Myr. *Basin Research*, 19: 105-123.

Barrends, F.B.J., Bronwer, F.J.J., Schroeder, F.H. (eds) (1995): *Land subsidence*. International Association of Hydrological Science. Publication 234 (IAHS Wallingford): 492 p.

Bartoletti, C. Bertonati, M., Ionnilli, E. (1985): Qualità delle acque nel delta del Po: aspetti chimici. *Nova Thalassia*, 7: 59-112.

Bauer, E. (1980): *Los montes de España en la historia*. Ministerio de Agricultura. Madrid: 376 p.

Baxter, P.J. (1953): The East Coast Big Flood, 31 January-1 February 1953: a summary of the human disaster. In: A., McRobie, T., Spencer, and H. Gerritsen (eds.), *The Big Flood: North Sea storm surge*. The Philosophical Transactions of the Royal Society, A. 363: 1293-1312.

Bishop, A.C., Bisson, C. (1989): *Jersey: description of 1:250.000 channel Islands Sheet 2*. British Geological Survey, London, Her Majestey´s Stationery Office: 126 p.

Boehm, P. (2006): Global warming: devastation of an atoll. *The Independent*, August 30.

Bourke, M. (1987): Dam blamed as West African Coastline disappears. *New Scientist*, 13 January: 21 p.

Bruckner, H. (1997): Coastal changes in western Turkey; rapid delta progradation in historical time. In: F. Briand and A. Maldonado, (eds.), *Transformations and evolution of the Mediterranean coastline*. CIESM Science Series nº 3, *Bulletin Institut Oceanographique. Monaco*, 18: 63-74.

Burgen, S. (2002): Down their drain. *Sunday Times* colour supplement, 21: 56-62.

Cabognin, L., Cecconi, G. (1997): *The Lagoon of Venice, environment, problems remedial measures*. Booklet published on the occasion of IAS-SEPM Meeting. Venice, October CNR: 71 p.

Ceballos, A., Ortuño, F. (1977): *Los bosques españoles*. INCAFO: 407 p.

Cearreta, A., Irabien, M.J., Leorri, E., Yusta, I., Croudance, I.W., Cundy, A.B. (2000): Recent anthropogenic impacts on the Bilbao estuary, northern Spain: geochemical and microfaunal evidence. *Estuarine, Coastal and Shelf Science,* 50: 571-592.

Cetin, H., Bal, Y., Demirkol, C. (1999): Engineering and environmental effects of coastline changes in Turkey, Northeastern Mediterranean. *Environmental and Engineering GeoScience*, 5: 315-330.

Clout, H.D. (1980): *Agriculture in France on the eve of the Railway Age*. London, Croom Helm: 225 p.

Clout, H.D. (1983): *The land of France, 1815-1914*. London. George Allen and Unwin: 252 p.

Cobelo-García, A., Prego, R., Labandeira, A. (2004): Land input of trace elements, major elements, particulate organic carbon and suspended solids to an industrial coastal bay of the NE Atlantic. *Water Research*, 38: 1753-1764.

Cockburn, D. (2007): Disaster looms as "Saddam dam" struggles to hold back the Tigris. *The Independent*, August 8.

Collazo, J.L., Pascual, C. (1997): Contenido en cobre, plomo, hierro y cromo en los biodepósitos de mejillones cultivados en la Ria de Arousa (NO España). In**:** Prego, R., and Fernandez, L. (eds.), *Procesos Bioquímicos en Sistemas Costeros Hispano-Lusos*. Pontevedra, España: 73-77.

Collins, M.B., Evans, G. (1986): The influence of fluvial sediment supply on coastal erosion in West and Central Africa. *Shoreline Management*, 2: 5-12.

Connor, S. (2007): Migrating bird´s habitat threatened by seawall. *The Independent*, May 12.

Conzen, M.P. (1980): The wood land clearances. *Geographical Magazine*, LII, April: 483-491.

Cooper, S.R. (1999): A journey thorough time. *Geotimes*, May: 14-18.

Cossu, R., Fragipane, E. De Fraja, (1987): Stato delle conoscenze sullìnquinamento della laguna di Venezia. Aspetti riassuntivi e conclisivi Att i della Giornata di Studio: a ventánni dall evento della marea del 1966. *1st Veneto Scienza Lettre Art*, Venezia, 1: 1-25.

Costa, J. (1975): Effects of agriculture on erosion and sedimentation in the Piedmont Province, Maryland. *Geological Society of America Bulletin*, 86: 1281-86.

Costanza, R., d´Arget, R., de Groot, R., Farber, S., Grosso, M., Hannon, B., Limburg, K., Naeem, S., O´Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M. (1997): The value of the world´s ecosystem services and natural capital. *Nature*, 387: 253-260.

Darby, H.C. (1940): *The drainage of the Fens*. Cambridge University Press: 314 p.

Davis, R.A. Jr., Barnard, P.L. (2000): How anthropogenic factors in the back-barrier area influence tidal inlet stability: example from the Gulf Coast of Florida USA. In: K. Pye, and J.R.L. Allen, (eds.), *Coastal and estuarine Environments: Sedimentology, Geomorphology and Geoarcheology*. Geological Society of London, Special Publication, 175: 293-303.

Dedkov, A.P., Mozzherin, V.I. (1992): Erosion and sediment yield in mountain regions of the world. In: D.E. Walling, T.R. Davies, and B. Hasholt (eds.), *Erosion, Debris Flows and Environments in Mountain Regions* (Procceding of the Chengdu Symposium, July 1992). International Association Hydrological Science, Publication 209: 29-36.

Díaz-Ferros, F. Gilsutres, F., Cabaneiro, A., Carballas, T., Leiros De La Pena, M.C., Villar Celorio, M.C. (1982): Efectivos erosivos de los incendios forestales en suelos de Galicia. *Annals Edafología Agrobiología*, 4: 627-639.

Dolan, R., Godfrey, P.J., Odum, W.E. (1973): Man´s impact on the barrier islands of North Carolina. *American Scientist*, 61: 152-162.

Dolan, R., Lins, H. (1975): Beaches and barrier islands. *Scientific American,* 275: 52-59.

Eisma, D. (1962): Beach ridges near Seljuc Turkey. Tijdchrift, Koninklijk Nederlands *Aardrijkskundig Genootschap*, Reeks LXXIX: 234-246.

Eisma, D. (1978): Stream deposition and erosion by the eastern shore of the Aegean. In: W.C. Brice (ed): *The Environmental History of the Middle East*. Academic Press London: 67-79.

Elliot, M. (2007): "It´s the economy, stupid": the view from the chair. *Bulletin Estuarine and Coastal Sciences Association*, 51: 3-4.

El Sayed, M.Kh. (1996): Rising sea-level and subsidence of the northern Nile delta: a case study. In: J.D. Milliman and B.U. Haq, (eds.), *Sea level rise and coastal subsidence: causes, consequences and strategies.* Kluwer Academic Publishers, Dordrecht: 215-233.

Evans, G., Collins, M.B. (1987): Sediment supply and deposition in the Wash. In: P. Doody, and B. Barnett, (eds.), *The Wash and its environment*. Nature Conservancy Council, Peterborough: 18-63.

Evans, G., Howarth, R.J., Nombela, M.A. (2003): Metals in the sediments of Ensenada de San Simón, inner Ría de Vigo, Galicia, NW Spain, *Applied Chemistry*, 18: 973-996.

Fillenham, L.F. (1963): Holme Fen Post. *Geographical Journal*, 129: 502-503.

Finkl, C.W., Walker, H.J. (2002): *Beach nourishment*. In: J. Chen, D. Eisma, K. Hotta and H. J. Walker (eds.), Engineered Coast. Kluwer Academic Publishers, Dordrecht: 1-22.

Finkel, A. (2000): Roman mosaics win reprieve from Turkish leader. *Times*. June 6.

Fischetti, M. (2005): Drowning New Orleans. *Scientific American*, 285: 68-77.

Fischetti, M. (2005): Protecting New Orleans: *Scientific American*, 286: 47-53.

Fowler, G. (1933): Shrinkage of the peat covered Fenlands. *The Geographical Journal,* LXXXI: 149-150.

García-Luque, E., Saenz, I., Riba, I., Del Valla, A., Forja, J.M., Gómez-Parra, A. (2003): Metales pesados en el estuario del Guadalquivir. *Ciencias Marinas*, 29:457-468.

Gerges, M.A. (1993): On the impact of the 1991 Gulf War on the environment of the region: general observations. *Marine Pollution Bulletin,* 27: 305-314.

Gerritsen, H. (1953): What happened in 1953? The Big Flood in the Netherlands in retrospect. In: McRobie, A., Spencer, T., Gerritsen, H. (eds.), *The Big Flood: North Sea Storm surge*. The Philosophical Transactions of the Royal Society, A., 363: 1271-1291.

Gill, A.A. (2000): The Dead Sea. *Sunday Times* Magazine. July 16: 33-39.

Ginns, M. (1973): Grouville Common during the German Occupation. *Bulletin Annual Sócieté Jersiase*, 21: 195-199.

Glantz, M.H. (ed.) (1999): *Creeping environmental problems and sustainable development in the Aral Sea Basin*, Cambridge University Press: 291 p

Glanz, J. (2005): *El incierto renacer de los iraquíes*. El País, April 14.

Glopper, R.J. de (1973): *Subsidence after drainage of the deposits of the former Zuyder zee and in the brackish and marine forelands in the Netherlands*. Van Zee Tot Land, 50, Staatsnitgeverij den Haag, The Nethelands: 205 p.

González, M., Uriarte, A., Pozo, R., Collins, M.B. (2005): The Prestige crisis: operational oceanography applied to oil recovery by the Basque fishing fleet. *Marine Pollution Bulletin*, 53: 369-374

González, M., Uriarte, A., Pozo, R., Collins, M.B., Ferrer, L. (2005): The Prestige crisis: operational oceanography applied to one recovery by the Basque fishing fleet and the study of long-term environmental impacts. *Oil spills in marine Ecosystems: Impacts and Remediation ICES.CM*, Sept, 20-24:1-11.

Grant, U.S. IV (1938): Geological problems involved in the conservation of beaches. *Pacific Southwest Academy Publication,* 16: 27-28.

Grimston, J. (2007): Swim in British waters at your peril, *Sunday Times*, July 10.

Grunwald, M. (2007): The threatening Storm: Special Report, New Orleans, *Time*, 170: 14-25.

Guillén, J., Palanques, A. (1992): Sediment dynamics and hydrodynamics in the lower course of a river highly regulated by dams: the Ebro. *Sedimentology*, 39:567-579.

Guillén, J., Palanques, A. (1997): A historical perspective of the morphological evolution in the Ebro river. *Environmental Geology,* 30: 174-180.

Gunatilaka, A. (in press): wave impacts, flow regimes and the onshore depositional architechture of the 2004 Indian Ocean tsunami in Sri-lanka. *Sedimentology*.

Hails, J. (1975): Start Bay. *Journal Geological Society London*, 131: 1-5.

Halim, Y., Gerges, S.K. (1981): Coastal lakes of the Nile delta: Lake Manzala. Symposium on coastal lagoons UNESCO. *Technical Papers in Marine Sciences*, 33: 135-172.

Haq, B.U. (1997): Regional and global oceanographic, climatic, and geologic factors in coastal zone planning. In**:** B.U. Hag, S.M. Haq,, G. Kultenberg, and J.H. Skel, (eds.), Coastal zone management imperative for maritime developing nations. *Kluwer Academic Publishers*, Dordrecht: 55-74.

Hekstra, G.P. (1988): *Prospects of sea-level rise and its policy consequences. Discussions paper for a symposium on controlling and adapting to greenhouse warming*. Washington D.C: 112 p

Hoff, R.W. Van (1994): Trends in the wave climate of the Atlantic and the North Sea: evidence and implications. *Journal Underwater Technology,* 19: 20-23.

Howarth, R.J., Evans, G., Croudance, I.W., Cundy, A.B. (2005): Sources and timing of anthropogenic pollution in the Ensenada de San Simón (inner Ría de Vigo), Galicia, NW Spain: an application of mixture modelling and non linear optimization to recent sedimentation. *Science of the Total Environment*, 340: 149-176.

Howells, R. (2000): *Amroth: A Brief History*. Gomer Press, Llandysul, Ceredigion, Wales: 32p.

Howells, R. (2003): *Old Saundersfoot, from Monkstone to Marros*. Gomer Press, Llandysul, Ceredigion, Wales: 132p.

Ibe, A.C. (1988): *Coastline erosion in Nigeria*. Ibadan University Press, Ibadan, Nigeria: 217 p.

Inglis, Sir C.C., Kestner, F.J.T. (1958): The long term effects of training walls, reclamation and dredging in estuaries. *Proceedings Institute of Civil Engineers*, 9: 193-257.

Inman, D.L., Frautschy, J.D. (1966): Littoral processes and the development of shorelines. Coastal Engineering Speciality Conference 1965, *American Society of Civil Engineers*: 511-536.

Inman, D.L., Jenkins, S.A. (1984): The Nile littoral cell and man´s impact on the coastal zone of the south east Mediterranean. 19th Coastal Engineering Conference Proceeding. *American Society Civil Engineers* Houston Texas: 1600-1617.

IOPC (2003): *Annual Report of International Oil Compensation Fund*, London. UK.

Kaufman, W., Pilkey, O.H. Jr. (1983): *The beaches are moving*, Duke University Press, Durham, North Carolina, USA: 336 p.

Jelgersma, S. (1996): Land subsidence in coastal lowlands. In: J.D. Milliman and B.U. Haq, (eds.), *Sea level rise and coastal subsidence*. *Kluwer Academic Publishers*, Netherlands: 47-62.

Jiménez, J.A., Sanchez-Arcilla, A., Valdemoro, H.I., Gracia, V., Nieto, F. (1997): Processes reshaping the Ebro delta. *Marine Geology,* 144: 59-79.

Jiongxin, Xu. (1993): A study of long-term environmental effects of river vegetation on the Yellow river of China in historical perspective. *Geografiska Annaler*, 75: 61-72.

Johnson, J. W. (1956): Dynamics of nearshore sediment movement. *Bulletin American Association Petroleum Geologist*, 40: 2211-2232.

Juniper, T. (2000): Ethical issues of Turkish dam. *Times*, July 17.

Krause, C.K., McDougal, W.G. (1996): The effect of seawalls on the beach: part 1, an updated literature review. *Journal of Coastal Research*, 12: 691-701.

Lambert, J.M., Jenning, J.N., Smith, C.T., Green, C., Hutchison, J.N. (1960): *The Making of the Broads: a reconsideration of their origin in the light of new evidence*. Royal Geographical Society Research Series, 3: 153 p.

Lee, D. (1983): The land of the river: the Mississippi delta. *National Geographic*, 164: 226-253.

Lee, J., Bulloch, J. (1990): Spirit of war moves on Mid-east waters. *The Independent Sunday*. May 13.

Li, X., Shen, Z., Wai, O.W.H., Li, Y.S. (2001): Chemical forms of Pb, Zn, Cu, in the sediment profiles of the Pearl river Estuary. *Marine Pollution Bulletin*, 47: 215-255.

Literathy, P. (1993): Considerations for the assessment of environmental consequences of the 1991 Gulf War. *Marine Pollution Bulletin*, 27: 349-356.

Lubick, N. (2003): Iraq´s marshes renewed. *Geotimes,* Oct: 25-27.

Lynagh, N. (1997): Weather and Climatic Variability since Prehistoric times and Recent indications of continued fluctuations in the NE Atlantic. *Journal Society Underwater Technology,* 22: 55-67.

McGirk, J., Buncombe, A. (2005): Damned to Oblivion. *The Independent*, April 5.

Mckie, R. (1997): Damming major rivers is pulling the Gulf stream nearer. How a saltier Mediterranian will make Europe notter. *Observer*, 30 Nov.

Meade, R.H., Trimble, S.W. (1974): Changes in sediment loads in rivers of the Atlantic drainage of the United States since 1900. *Publication of the International Association of Scientific Hydrology*, 113: 99-104.

Miller, B.S., Pirie, D.J., Redshaw, C.J. (2000): An assessment of the contamination and toxicity of marine sediments in the Holy Loch, Scotland. *Marine Pollution Bulletin*, 40: 22-35.

Milliman, J.D. (1997): Effect of terrestial processes and human activities on river discharge and their impact of the coastal zone. In: B.U. Haq, S.M. Haq, G. Kullenberg and J.H. Stel (eds.), *Coastal Zone Management imperative for maritime developing nations*. Kluwer Academic Publishers, Dordrecht: 75-92.

Milliman, J.D., Haq, B.U. (eds) (1996): *Sea level rise and coastal subsidence: causes, consequences and strategies*. Kluwer Academic Publications, Amsterdam: 369 p

Montgomery, D.R. (2004): Geology, Geomorphology and the restoration ecology of salmon. *Geological Society America*, Today 14: 4-12.

Morgan, R. (2000): Ethical Issues of Turkish dams. *Times*, July 17.

Mourant, A. E. (1956): The use of Ecréhous stone in Jersey. *Bulletin Annual Société Jersiase*, 16: 373-376.

Nagel, I., Lang, F. (2003): Guadiamar toxic flood: factors that govern heavy metal distribution in soils. *Water, Air and Soil Pollution*, 143: 211-222.

Nash, E. (2006): Fishermen face ruin as Spanish fires trigger deadly black tide. *The Independent*, October 27.

Nash, E. (2007): Mediterranean drowning in a hidden sea of plastic rubbish, *The Independent*, July 18.

Nelson, S.A., Leclair, S.F. (2006): Katrina´s unique splay deposit in a New Orleans neighbourhood. *Geology*, 16: 4-10.

Nicolaidou, A., Nott, J.A. (1998): Metals in sediments, seagrass and gastropods near a nickel smelter in Greece: possible interactions. *Marine Pollution Bulletin*; 36: 360-365.

Nikonov, A.A. (1977): Contemporary technogenic movements of the Earth´s crust. *International Geology Review*, 19: 1245-1258.

Nutalaya, P., Chandra, S., Balasubramiam, A.S. (1986): Subsidence of Bangkok Clay due to deep water well pumping and its control through artificial discharge. *International Association Hydrological Sciences Publication*, 151: 727-744.

Norris, R.M. (1964): Dams and beach sand supply in Southern California. In: R.L. Miller, (ed): Papers in marine geology. Shepard Commemorative Volume, *The Macmillan Company*, New York: 154-171.

O'Connor, B.A. (1987): Short and long term changes in estuary capacity. *Geological Society London Journal*, 144:187-195

Olias, M., Ceron, J.C., Fernandez, I and Moral, I. (2005): State of contamination of the soils of the Guadiamar River five years after the Aznalcollar spill. *Water, Air and Soil Pollution*, 166: 103-119.

Pearce, F. (1991): A dammed fine mess. *New Scientist*, May 4: 36-39.

Pearce, F. (1992): *The dammed: rivers, dams and the coming world water crisis*,. The Bodley Head, London. 376 p.

Pearce, F. (2006): Mega-dams back on the agenda*. New Scientist*, May 19: 10.

Pereira, H.C. (1973): *Land use and water reserves in temperate and tropical climates*. Cambridge University Press, Cambridge: 246 p.

Petzelberger, B.E.M. (2000): Coastal development and human activities in NW Germany. In: K.Pye, and J.R.L. Allen (eds.), *Coastal and Estuarine Environments: Sedimentology, Geomorphology and Geoarcheology*. Geological Society London, Special Publication, 175: 365-376.

Pilkey, O.H. (2003): *A celebration of the world´s barrier islands*. Columbia University Press, New York: 309 p.

Popham, P. (2001): Protest as author faces charges over project (Sardar Sarovar dam). *The Independent*, April 24.

Poulos, S.E., Chronis, G. Th., Collins, M.B., LyKousis, V. (2000): Thermaikos Gulf coastal System, N.W. Aegean: an overview of water/sediment fluxes in relation to air-land-ocean interactions and man´s activities. *Journal Marine Systems*, 25: 47-76.

Poulos, S.E., Collins, M.B. (2002): *Fluviatile sediment fluxes to the Mediterranean sea: a quantitative evaluation of riverine/water sediment fluxes*. In: L.E. Fostick, and S. Jones, (eds.), Sediment Flux to Basins: Controls and consequences. *Geological Society London*, Special Publication 191: 227-245.

Price, W.A., Kendrick, M.P. (1963): Field and model investigations into the reasons for siltation in the Mersey Estuary. *Proceedings Institute of Civil Engineers*, 24: 473-517.

Ravera, O. (2000): The Lagoon of Venice: the result of both natural factors and human influence. *Journal of Limnology*, 59: 19-30

Ren, M., Xianmo, Zha. (1994): Antropogenic influences on changes in the sediment load of the Yellow River, China, during the Holocene. *The Holocene*, 4: 314-320.

Richards, C. (1990): Conflict over water threatens Near East. *The Independent*, November, II.

Richardson, S.J., Smith, J. (1977): Peat wastage in the East Anglian Fens. *Journal of Soil Science*, 28: 485-559.

Rivas, M. (2006): La huella de un infierno. *El País Semanal*, 1570, 29 Octubre: 35-49.

Rose, E.P.F. (2005): Impact of military activities on local and regional geologic conditions. In: J. Ehlen, W.C. Haneberg and R.A. Larsen (eds.), Humans as geologic agents. *Review in Engineering Geology*, XVI, Geological Society of America: 51-66.

Rose E.P.F., Pareyn, C. (1995): Geology and liberation of Normandy, France, 1944. *Geology Today*, 11: 58-63.

Rose E.P.F., Pareyn, C. (2003): Geology of the D-Day landing in Normandy, 1944. *Geologist´s Association Guide*, 64, London, UK: 1-98.

Roy, P.S., Crawford, (1984): Heavy metals in a contaminated

Australian estuary: dispersion and accumulation trend. *Estuarine, Coastal and Shelf Science,* 19: 341-358.

Ruiz, F. (2001): Trace metals in estuarine sediments from the south-western Spanish coast. *Marine Pollution Bulletin*, 42: 482-490.

Runnels, C.N. (1995): Environmental degradation in ancient Greece. *Scientific American*, 287: 72-75.

Sala, M., Rubio, J.L. (eds) (1994): *Soil erosion and degradation as a consequence of forest fires*. Geoforma Ediciones. Logroño: 273 p.

Sala, M., Rubio, J.L., García-Ruíz, J.M. (eds) (1991): *Soil erosion studies in Spain.* Geoforma Edic., Logroño: 228 p.

Schwarz, W. (1985): A rude awakening from the scourge of the dam builders, *Guardian*, May, 25.

Sestini, G (1976). Geomorphology of the Nile delta. In: UNDP/ UNESCO. Proceedings of a seminar on Nile delta sedimentation. *Sedimentology, Academy of Scientific Research and Technology*. Alexandria Egypt: 12-24.

Sestini, G. (1992): Implications of climatic changes for the Nile delta. In: Jeftic, L., Milliman, J.D., Sestini, G. (eds.), *Implications of climatic change in the Mediterranean Sea*, Pergamon Press: 428-494.

Sharaf el Din, S.H. (1977): Effects of the Aswan High Dam on the Nile flood and the estuarine and coastal circulation pattern along the Mediterranean Egyptian coast. *Limnology and Oceanography*, 22: 194-207.

Shewstack, R. (2000): Report on large dams calls for balance ancient of projects and revised decision making processes. EOS, *Transactions of American Geophysical Union*, 81: 593-599.

Shinn, E.A. (1973): *Sedimentary accretion along the leeward southeastern coast of the Qatar peninsula, Persian Gulf*. In: B.H. Purser (ed): The Persian Gulf, Springer-Verlag. Berlin: 199-210.

Silvester, R. (1950): Engineering aspects of coastal sediment movement. Journal Waterways Harbour Division. *American Society of Civil Engineers*, WW3: 11-39.

Stanley, D.J., Warne, A.G. (1993): Nile delta: recent geological evolution and human impact. *Science*, 260: 628-634.

Steers, J.A. (1948): *The coastline of England and Wales*. Cambridge University Press, Cambridge: 644 p.

Stein, N. (2003): Galicia *Prestige, Report book*, Adena, Viking SA Madrid: 145 p.

Sultan, M. Becker, R., Al-Dousari, Al-Ghadan, A.N., Bufano, E. (2003): Water, Agriculture and land cover: lessons for the past-war era. *Geotimes*, October: 22-24.

Symonds, A.M., Collins, M.B. (2004): Sediment dynamics associated with managed realignment: Frieston Shore, The Wash, UK. In: J. Mckee Smith (ed.) *Proceedings 29th International Conference Coastal Engineering, Lisbon, Portugal, 3 World Scientific Publishing Company*: 3173-3185.

Tanner, P., Leong, L.S., Pan, S.H. (2000): Contamination of heavy metals in marine sediment cores from Victoria harbour, Hong Kong. *Marine Pollution Bulletin*, 40: 769-799.

Verger, F. (1985): *Marais et wadden du Littoral Français*.., Paradigme, Caen: 549 p

Vita-Finzi, C. (1969): *The Mediterranean Valleys*., Cambridge University Press, Cambridge: 140 p

Wagret, P. (1968): *Polderlands*. Methuen, London: 342 p

Walker, H.J., Davis, D.N. (2002): *The Mississippi river: Engineered routes to the sea*. In: J.Chen, D. Eisma, K. Hotta and H.J. Walker (eds.), Engineered Coast, Kluwer Academic Publishers, Dordrecht: 61-94.

Walling, D.E., Gregory, K.J. (1970): The measurement of the effects of building construction on drainage basin dynamics. *Journal of Hydrology,* 11: 129-144.

Waltham, T. (1989): *Ground subsidence*. Blackie London: 202 p

Waltham, T. (2002): Sinking cities. *Geology Today*, 18: 95-100.

Waltham, T. (2005): The flooding of New Orleans. *Geology Today*, 21: 225-231.

Waltham, T., Sholiji, I. (2001): The demise of the Aral Sea –an environmental disaster. *Geology Today*, 17: 215-224.

White, D. (2005): What happens to oil spills, *Geoscientist*, 15: 5-11.

Wilkinson, B.H. (2005): Humans as geologic agents: a deep time perspective. *Geology*, 30: 161-164.

Williams, M.R., Milward, G.E. (1998): Dynamics of particular trace elements in the tidal reaches of the Ouse and Trent, UK. *Marine Pollution Bulletin*, 37: 306-315.

Wilson, E.M. (1979): Tidal power projects in Canada, India and Korea. In: R.T. Severn, D.L. Dineley and L.E. Hawker (eds.), *Tidal Power and estuary management.* Procedeedings 13th Symposium, Colston Research society, Bristol Scientechnica: 99-114.

Wolman, M.G. (1967): A cycle of sedimentation and erosion in urban river channels. *Geografiska Annaler*, 494: 385-395.

Wolman, M.G., Schick, A.D. (1967): Effects of construction on fluvial sediment, of urban and suburban areas of Maryland. *Water Resources Research*, 3: 451-464.

Woodward, J.C. (1995). Patterns of erosion and suspended sediment yield in Mediterranean river basins. In: I.D.L. Foster, A.M. Gurnell and B.W. Webb (eds.), *Sediment and Water quality in River Catchments*,. John Wiley and Sons Ltd., New York: 365-389

Worth, H.R. (1904): Hallsands and Start Bay. Reports of the Transactions of the Devonshire *Association for the Advance of Science*, (a) 36: 302-346 and (b) 37: 301-308.

Zengcui, H., Zeheng, D. (2002): *Reclamation and river training in the Qiantang estuary.* In: J.Chen, D. Eisma, K. Hotta and H.J. Walker (eds.), Engineered Coast, Kluwer Academic Publishers, Dordrecht: 121-138.

Zhang, X., Zwiers, F.W., Heder, C., Lambert, F.H., Gilett, N.P., Solomon, S., Stott, P.A., Nozawa, T. (2007): Detection of human influence on twentieth precipitation trends. *Nature*, London, 448: 461-465.

Zuchetta, G. (1983): L'inquinamento della laguna veneta. *Ateneo Veneto*, 21: 5-14.