ACCADEMIA NAZIONALE DEI LINCEI

XIX GIORNATA MONDIALE DELL'ACQUA

Convegno

GESTIONE E DIFESA DELLE COSTE

21 marzo 2019

PROGRAMMA

Comitato Ordinatore: Ernesto CAPANNA, Michele CAPUTO, Bruno CARLI, Annibale MOTTANA, Giuseppe OROMBELLI (Coordinatore)

FASCICOLO ABSTRACT

9.30 Saluto della Presidenza dell'Accademia

Giuseppe OROMBELLI (Linceo, Università di Milano-Bicocca): Apertura dei lavori

10.00 Enzo PRANZINI (GNRAC - Università di Firenze): *Erosione e difesa dei litorali: una sfida per la scienza e la società*

10.30 Antonio GOLINI (Linceo, Sapienza Università di Roma) - Stefano TERSIGNI (ISTAT, Roma): *Pressione antropica sulle coste italiane*

11.00 Intervallo

11.15 Pier Luigi AMINTI (GNRAC - Università di Firenze): *Onde sotto costa: correnti ed interazioni con le opere di difesa*

11.45 Enrico FOTI (Università di Catania): *Tecniche di difesa costiera e cambiamenti climatici*

12.15 Giuseppe MASTRONUZZI (Università di Bari): *Evidenze geologiche di tsunami sulle coste del Mediterraneo*

12.45 Discussione

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14.00 Carlo BRANDINI, Massimo PERNA, Stefano TADDEI (Consorzio LaMMA, Sesto Fiorentino) - Gianfranco BONINSEGNI, Luigi E. CIPRIANI (Regione Toscana): *Monitoring, risk forecasting and coastal planning in the Region of Tuscany*

14.15 Giuseppe ESPOSITO (CNR- IRPI, Rende) - Fabio MATANO, Marco SACCHI (CNR- ISMAR, Napoli) - Riccardo SALVINI (Università di Siena): *Multi-temporal analysis of dismantling coastal cliffs in the* Campi Flegrei *volcanic area, Italy*

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14.45 Gianluigi BUSICO, Micòl MASTROCICCO (Università della Campania 'Luigi Vanvitelli', Caserta) – Maria-Margarita NTONA, Elisavet GAVRIILIDOU, Nerantzis KAZAKIS (Aristotle University of Thessaloniki) - Nicolò COLOMBANI (Università Politecnica delle Marche, Ancona): *Limitations of using weighting-rating and quality index methods to assess seawater intrusion: the case study of Thermaikos Gulf (Greece)*

15.00 Daniela PAGANELLI, Paola LA VALLE, Monica TARGUSI (ISPRA, Roma): *Potential sediment resources for coastal defence strategies*

15.15 Maria Cristina BUIA, Lucia PORZIO (Stazione Zoologica Anton Dohrn, Napoli): *Soft and hard coastal transformation: effects on benthic marine habitats around the coasts of the Ischia island*

15.30 Livio C. PICCININI (IPSAPA/ISPALEM, Udine) - Ting Fa Margherita CHANG, Luca ISEPPI, Maurizio DROLI (Università di Udine): *Low coast development and environmental protection in Italy: from history to the future*

15.45 Giovanni RANDAZZO, Stefania LANZA (Geologis SRL, Università di Messina): *The beach is moving: a resilient approach for defending a fragile system*

16.00 Enrica VECCHI, Stefano GANDOLFI (Università di Bologna) - Margherita AGUZZI, Maurizio MORELLI (Arpae–Regione Emilia-Romagna) - Carlo ALBERTAZZI (Regione Emilia-Romagna) - Nunzio DE NIGRIS (GNRAC - Arpae Regione Emilia-Romagna): *Third beach nourishment project with submarine sands along Emilia-Romagna's coast: geomathic methods and first monitoring's results*

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Francesca SERIO, Adele IDOLO, Isabella GAMBINO, Tiziana GRASSI, Mattia DE GIORGI, Alessandra PANICO, Antonella DE DONNO, Francesco BAGORDO (Università del Salento, Lecce): *Marine coastal water quality and bathing tourism: impact of submarine springs along the coast of southeastern Salento (Apulia region, Italy)*

Nicola PIZZEGHELLO, Luigi SINAPI, Erik BISCOTTI (Istituto Idrografico della Marina, Genova): *Monitoring the evolution of the coasts for a sustainable Blue Growth*

Lorenzo PAPA (Istituto Idrografico della Marina, Genova): *Long period oscillations of sea level data in Genoa*

Giovanni MARTINO, Michele GRECO (Università della Basilicata, Potenza): *Expeditive coastal flooding scenarios assessment induced by long term climate changes*

Davide BONALDO (CNR-ISMAR, Venezia) - the CHANGE WE CARE Team (CNR-ISMAR, Venezia - Regione Emilia-Romagna, Bologna – Parco del Delta Po, Comacchio – ISPRA, Roma – Regione Autonoma Fiuli Venezia Giulia, Trieste – Regione Veneto, Venezia - University of Zagreb - Public Institution for Management of Protected Natural Areas of Dubrovnik-Neretva County, Dubrovnik - Institute of Oceanography and Fisheries, Split - Public Institution for Coordination and Development of Split-Dalmatia County, Split - Public Institution Vransko Lake Nature Park, Zadar): *Climate change assessment, monitoring and adaptation at trans-boundary level: the EU Interreg CHANGE WE CARE project*

Giovanni SCARDINO, Massimo MORETTI, Isabella LAPIETRA, Stefania LISCO, Giuseppe MASTRONUZZI (Università di Bari 'Aldo Moro') - Arcangelo PISCITELLI, Maurilio MILELLA, Paola FAGO, Francesco DE GIOSA, Giovanni BARRACANE, Giuseppe LOCURATOLO (Environmental Surveys Srl) - Alessandro CICCOLELLA (Consorzio di Gestione di Torre Guaceto): *Anthropic impact conditioning pocket beach evolution of* Torre Guaceto (Carovigno, Brindisi)

Rosaria Ester MUSUMECI, Massimiliano MARINO, Enrico FOTI (Università di Catania) - Carla FARACI, Carmelo PETROTTA, Alessia RUGGERI, Lilia CARLO, Giovanni SAVASTA (Università di Messina) - Giuseppe BARBARO (Università di Reggio Calabria): *Wave current interaction over rough beds*

Irene MAMMÌ, Lorenzo ROSSI (Gruppo Nazionale per la Ricerca in Ambiente Costiero, Genova) - Enzo PRANZINI (Università di Firenze): *Morphodynamic evolution of the Ombrone River delta through mathematical reconstruction of beach ridges*

Rosaria Ester MUSUMECI, Laura Maria STANCANELLI, Enrico FOTI (Università di Catania) - Riccardo BRIGANTI (University of Nottingham): *Erosional processes at the toe of a flood defense structure during sea storm sequences*

Diana DE PADOVA, Elvira ARMENIO, Francesca DE SERIO, Michele MOSSA, Antonio F. PETRILLO (Politecnico di Bari): *Statistical correlation and GIS analysis to evaluate shoreline evolution*

Maria Laura CARRANZA, Flavio MARZIALETTI, Maria Carla DE FRANCESCO, Angela STANISCI (Università del Molise, Pesche) - Mita DRIUS (CNR-ISMAR, Venezia): *Urban expansion depletes cultural ecosystem services. An insight into the Mediterranean coastline*

Lyuba NOVI, Serena BOTTEGHI, Francesco RAFFA (IGG-CNR, Pisa) - Duccio BERTONI, Giovanni SARTI (Università di Pisa) - Fabrizio LIRER (ISMAR-CNR, Napoli): *Wave climatology and energy transport as an assessment tool for coastal erosion mitigation solutions*

Silas DEAN, Duccio BERTONI, Giacomo BRUNO, Marco MENCARONI, Giovanni SARTI (Università di Pisa) - Arthur C. TREMBANIS (University of Delaware, USA): *Pre- and post-storm sedimentological characterization of an artificial coarse-clastic beach*

Marco MARINELLI, Paolo CONTINI (Consulenti tecnici SMM SpA "Marina Sveva") - Maria Pina IZZO, Agostino FRANCISCHELLI, Mauro DI MUZIO, Annunziata DI NIRO, Emilio LECCESE (Regione Molise): *Reuse of dredging sediment: the case study of* "Marina Sveva" *port – (Italy)*

Gianluigi DI PAOLA, Carmen M. ROSSKOPF (Università del Molise, Pesche) - Pietro P.C. AUCELLI (Università di Napoli 'Parthenope') - Angela RIZZO (Centro Euro-Mediterraneo sui Cambiamenti Climatici) - Germán RODRÍGUEZ (Universidad de Las Palmas de Gran Canaria): *Mid-term shoreline evolution and beach erosion along the southern coast of Gran Canaria Island (Spain)*

Angela RIZZO (Centro Euro-Mediterraneo sui Cambiamenti Climatici) - Gaia MATTEI, Pietro AUCELLI (Università di Napoli 'Parthenope') – Giorgio ANFUSO, Javier F. GRACIA (University of Cadiz): *The vulnerability of the coastal archaeological sites located along the Posillipo Hill (Gulf of Naples, Italy)*

Manlio PALMAROCCHI (STES, Roma) - Pierfranco VENTURA (Sapienza Università di Roma): *New defense of the natural nourrishment and seabed grassland*

Nicola CANTASANO (ISAFOM Cosenza) - Federico BOCCALARO (AIPIN Lazio, Roma): *Soil bioengineering in the Mediterranean coastal environment*

Sara MORUCCI, Elisa CORACI, Franco CROSATO, Maurizio FERLA (ISPRA, Roma*): Extreme events in Venice and in the North Adriatic sea: 28-29 October 2018*

Elvira DE MATTHAEIS, Lucilla RONCI, Domenico DAVOLOS (Sapienza Università di Roma) - Alessandro CAMPANARO (CREA, Cascine del Riccio) - Marzio ZAPPAROLI (Università della Tuscia, Viterbo): *Faunistic assemblage of the supralittoral zone in the Thyrrhenian coast (Central Italy): the invertebrates inhabiting the Posidonia oceanica banquette*

David ROSSI, Emanuele ROMANO, Nicolas GUYENNON (CNR-IRSA, Monterotondo) – Edoardo CALIZZA (Sapienza Università di Roma) – Martina RAINALDI (MIUR): *Biodiversity response to a rapid water level oscillation: the case study of Lake Bracciano (Central Italy)*

Patrizia BORRELLO, Luisa NICOLETTI, Cecilia SILVESTRI (ISPRA, Roma): *Posidonia oceanica banquettes: a resource for the marine-coastal environment and a natural defence for the coasts*

Costantino SIGISMONDI (Sapienza Università di Roma) - Giovanni BERNARDINI (ITIS Armellini, Roma) - Valeria DE FELICE PROIA (ITIS Galilei Roma) - Benedetto SCOPPOLA (Università di Roma Tor Vergata) - Davide Mihai DRAGOS, Tommaso VASTOLA (ITIS Ferraris, Roma) - Giuseppina DE FELICE PROIA (ITIS Fermi Roma): *Measuring meteotsunamis in sea and connected inland waters with ultrasonic sensors*

17.30 Conclusioni

ROMA - PALAZZINA DELL'AUDITORIO - VIA DELLA LUNGARA, 230

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R E L A Z I O N I

Apertura dei lavori

Giuseppe OROMBELLI (Linceo, Università di Milano-Bicocca)

Le zone di confine sono zone fertili di incontri e di scambi ma pure sede di possibili inconvenienti e conflitti. Perciò le zone di confine vengono presidiate e, qualora occorresse, difese. I flussi in entrata e in uscita vanno gestiti perché permanga un sostanziale equilibrio dinamico. Ora le zone di confine tra i mari e le terre emerse è quanto indichiamo con il termine di coste. Ed esse sono zone di scambio di energia e di materia tra le acque marine e le rocce e i sedimenti, ma pure le acque dolci e la vita presenti sulle terre emerse adiacenti. E può accadere che una delle due parti a contatto prevalga sull'altra così che in entrambi i casi le coste vengono modificate, con conseguenze molto spesso negative dal punto di vista economico e sociale ma pure da quello ecologico e paesaggistico. Perché le coste sono un elemento del paesaggio spesso di notevole fascino e bellezza, costituiscono un ambiente peculiare nell'ambito della biodiversità, ricco di specie ad esso adattate, ospitano insediamenti, strutture, vie di comunicazione di rilevante importanza economica, nonché beni culturali di pregio storico e artistico. Infine, o localmente soprattutto, sono una importante risorsa economica e sociale legata al turismo balneare e nautico.

Il tema scelto per questo Convegno, il 19° organizzato dall'Accademia Nazionale dei Lincei in occasione della giornata mondiale dell'acqua, è stato suggerito dal Prof. Michele Caputo, presidente della Commissione per l'ambiente e le grandi calamità naturali, e riguarda appunto la cura che si deve dedicare alla conservazione e valorizzazione delle coste, da considerarsi come un patrimonio che assomma valori naturali, economici e culturali particolarmente preziosi.

Domani, sarà il *World Water Day*, la giornata mondiale dell'acqua, istituita dalle Nazioni Unite nel 1992 alla Conferenza sull'Ambiente e lo Sviluppo di Rio de Janeiro, per promuovere e difendere l'uso sostenibile delle risorse idriche. Dal 1993 si tiene ogni anno il 22 marzo. In Italia dal 2001, ogni anno in questa data o in un giorno quanto più prossimo, viene organizzato un convegno dalla Accademia Nazionale dei Lincei in Roma, dedicandolo volta a volta a temi connessi con l'acqua come risorsa, ma pure agli aspetti connessi con i rischi naturali o, come spesso si dice, idro-geologici.

Le coste sono quelle parti al margine delle terre emerse modellate direttamente o indirettamente dal mare: dal punto di vista geomorfologico vengono distinte in coste alte e coste basse. Le prime sono coste rocciose con scarpate più o meno inclinate fino a subverticali, di norma raggiunte dal moto ondoso al loro piede, e sono soggette essenzialmente a processi erosivi: le seconde sono invece costituite da materiali sciolti, da fini a molto grossolani che, provenendo principalmente dall'apporto fluviale, vengono trasportati, deposti e rimaneggiati dal moto ondoso e dalle correnti litorali. Sono quindi, in senso lato, le spiagge e sono il prodotto di un equilibrio tra processi costruttivi e processi erosivi. Esistono molti tipi diversi di coste sia alte sia basse, a sottolineare la varietà di forme e di paesaggi costieri, dagli atolli o le coste a mangrovie della fascia intertropicale, fino alle "barriere", cioè alle fronti verticali a mare delle gigantesche piattaforme di ghiaccio galleggianti dell'Antartide o ai fiordi e alle spiagge orlate dai ghiacci marini dell'Artide.

In Italia e nel Mediterraneo la varietà delle coste ci è più famigliare, dalle lagune ai lidi, alle grandi spiagge falcate, alle piccole e protette spiagge a tasche insinuate tra i promontori, alle falesie e alle coste alte, con la grande varietà di dettagli, grotte, archi, faraglioni, fino ai più minuti aspetti prodotti dalla varietà delle rocce scolpite dal mare. A ciò si aggiunge il fascino della storia e delle tracce lasciate da una antica presenza umana che risale alla preistoria.

Ma improvvisamente, con il boom economico degli anni '50-'60 del secolo scorso, le nostre coste hanno subito un attacco da parte del mare, causato in realtà da terra, dagli interventi e modificazioni operati dell'uomo. A questo proposito riporto un ricordo personale. Sul finire degli anni '60 fu tenuto un convegno a Riva degli Etruschi, tra San Vincenzo e il Golfo di Baratti, sul litorale toscano, in un autunno inoltrato. Al convegno, organizzato dal CNR, furono invitati i sedimentologi e geomorfologi italiani. Non eravamo molti, penso una dozzina, a seguire una serie di seminari e ricognizioni sul terreno tenuti da un geologo americano (J.W. Pierce dello Smithsonian Institution) esperto di erosione e bilancio dei sedimenti delle spiagge.

L’erosione delle spiagge si era improvvisamente affacciata a turbare le estati degli italiani, ai tempi di “tutti al mare”, di “con le pinne, il fucile e gli occhiali” o del romanzo di La Capria “Ferito a Morte”, premio Strega nel 1961, ove accanto al protagonista era la natura, giunta a noi incontaminata o quasi, che veniva percepita come ferita. Nacquero allora gruppi di ricerca un po’in tutte le sedi universitarie in Italia, coordinati nel progetto CNR *Dinamica dei litorali* e i risultati portarono tra il 1984 e il 1992 alla realizzazione progressiva di un *Atlante delle spiagge italiane*, che fu infine pubblicato dal CNR e dal MURST nel 1997, a cura di Giuliano Fierro. In una serie di carte al 100.000 sono raffigurate tutte le coste italiane, con notazioni che riguardano le opere portuali e gli interventi di difesa dei litorali, i tipi di coste e le loro caratteristiche morfologiche, emerse e sommerse, la tendenza evolutiva, distinguendo i tratti di costa in erosione e in accrescimento, la dinamica idrologica e sedimentologica e cioè le correnti litorali, il verso del trasporto solido, gli apporti fluviali, la granulometria e la petrografia dei sedimenti e molte altre informazioni ancora.

Da allora quello che era un settore di ricerca secondario è divenuto un campo di studi e di interventi esercitato a tempo pieno da numerosi ricercatori e professionisti. Gli interventi sulle coste italiane da sporadici sono divenuti via via più frequenti, con la realizzazione di strutture di difesa lungo costa o a mare, ripascimenti dei litorali sabbiosi, cioè riporti di sabbia prelevata dai fondali antistanti, tanto che attualmente lunghi tratti delle coste italiane sono fronteggiati da pennelli o altre strutture a mare o da strutture rigide lungo costa. I risultati di questi interventi non sempre sono stati risolutivi, quando anche non abbiano generato conseguenze, almeno in parte, negative. Lungo le coste alte le mareggiate hanno prodotto recentemente danni alle vie di comunicazioni o alle strutture portuali esistenti e fenomeni franosi sulle scarpate rocciose hanno messo a rischio la frequentazione dei lembi di spiaggia sottostanti. La lenta, diseguale, ma inesorabile risalita del livello del mare in atto da oltre un secolo e in accelerazione negli ultimi decenni, ha contribuito ad accentuare i fenomeni erosivi e, unitamente a eventi meteomarini estremi, ha ampliato la zona esposta all’aggressione delle mareggiate, come avvenuto nell’autunno 2018 a Rapallo e a Portofino; ha accentuato, particolarmente nelle zone in subsidenza per cause naturali (o anche antropiche), l’intrusione di acque saline negli acquiferi costieri. Che fare dunque per contrastare questi fenomeni, come contemperare le esigenze sociali ed economiche del turismo balneare con la preservazione del contesto naturale delle coste? Il convegno si propone di fare il punto sulla situazione, discutere le cause dei fenomeni, suggerire sulla base delle esperienze sin qui fatte le migliori soluzioni, sollevare anche l’attenzione su nuove (o trascurate) fonti di rischio. Il numero elevato di adesioni per interventi a questo convegno testimonia da un lato la vitalità di questo settore di studi e di interventi e dall’altra la gravità dei problemi che riguardano le nostre coste.

Erosione e difesa dei litorali: una sfida per la scienza e la società

Enzo PRANZINI (GNRAC - Università di Firenze)

L'erosione delle spiagge, iniziata nella seconda metà del XVIII secolo in conseguenza della riduzione dell'input di sedimenti da parte dei fiumi, sta ora accelerando a causa dell'innalzamento del livello del mare.
Durante questo periodo si è verificata una intensa urbanizzazione delle aree costiere, essendo queste un luogo privilegiato per l'insediamento di industrie, vie di comunicazione e strutture turistico-ricreative. I porti, funzionali a queste attività, hanno interrotto il trasporti dei sedimenti lungo riva, innescando hotspot erosivi che si estendono progressivamente sottoflutto alle strutture aggettanti in mare.
La linea di costa è stata inizialmente stabilizzata con scogliere aderenti, che hanno spesso fatto sparire la spiaggia e impedito un accesso sicuro al mare. Successivamente, anche in conseguenza del crescente valore economico della spiaggia, sono stati costruiti pennelli e scogliere parallele, nella speranza di mantenere un arenile, ma sempre a discapito di lunghi tratti costieri adiacenti. Molte spiagge sono state trasformate in coste rocciose, con una riduzione dello stesso valore economico che doveva essere protetto.

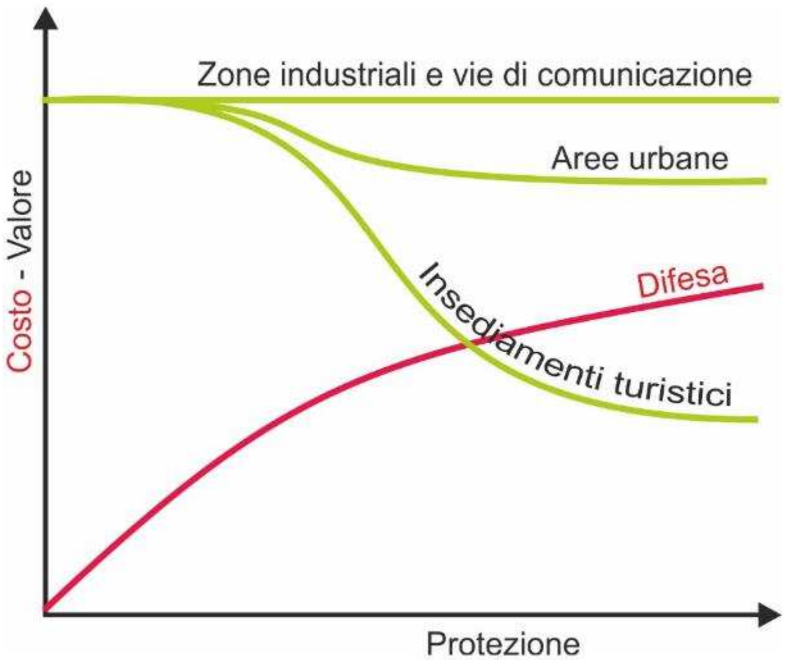

Figura 1. Una spiaggia vede ridursi il proprio valore economico (e certamente ambientale) al crescere delle opere di difesa che si vanno a realizzare. Ciò non riguarda i litorali su cui sono presenti esclusivamente vie di comunicazione o insediamenti industriali, ma avviene in misura progressivamente maggiore se vi sono aree urbane o zone turistiche, tanto che il costo della difesa potrebbe arrivare a superare il valore residuo della spiaggia.

Per compensare il bilancio sedimentario negativo dei litorali, sono stati effettuati ripascimenti artificiali, prima con materiale estratto dai fiumi e dalle pianure alluvionali – a cui si sono aggiunti quelli prodotti per frantumazione di rocce in cava -, poi con sedimenti prelevati dalla piattaforma continentale, dove formavano antiche spiagge nei periodi glaciali, quando il livello del mare era più basso di quello attuale.
Si tratta di risorse non rinnovabili e la cui estrazione, in ambiente estremamente delicato come il Mar Mediterraneo, pone non poche problematiche, limitando notevolmente le potenziali aree di prelievo.
Non è prevedibile un incremento dell'input sedimentario naturale, in quanto tutti progetti volti alla riduzione del rischio idrogeologico (stabilizzazione dei versanti e prevenzione delle alluvioni) determinano una riduzione della produzione dei sedimenti all'interno dei bacini idrografici e una maggiore difficoltà del loro trasporto verso il mare. Si ha quindi un conflitto d'interessi fra le popolazioni che vivono all'interno e quelle che vivono sulla costa: quest'ultime si avvantaggerebbero da un dissesto idrogeologico, quale quello che ha caratterizzato

molti periodi storici, e che ci ha lasciato in eredità pianure costiere orlate da larghe spiagge e da numerosi cordoni dunari.

La rimobilitazione dei sedimenti che sono stati intrappolati dagli invasi artificiali potrebbe contribuire all'alimentazione dei litorali per un consistente numero di anni, ma anche questa è una risorsa limitata e la sua utilizzazione potrebbe non essere sempre possibile per le caratteristiche granulometriche e eco-tossicologiche dei sedimenti.

Non potendo intervenire sulle cause dell'erosione, se non in misura ridotta e a scala locale, tre sono le strategie da attuare, non necessariamente in modo alternativo:

Difesa: non è altro che quanto fatto fino ad oggi, impedendo alla costa di arretrare nonostante la riduzione dell'input sedimentario e l'innalzamento del livello del mare, che porta anch'esso ad una perdita di sedimenti che migrano verso il largo (Legge di Bruun).

Adattamento: si tratta di adattare le strutture esistenti in base agli scenari previsti, innalzando la base delle costruzioni, dei piazzali e delle banchine dei porti, nonché dei moli foranei, delle vie di comunicazione e prevedendo un adeguamento delle canalizzazioni nelle aree già ora prossime al livello del mare.

Arretramento: è la soluzione suggerita da tutte le organizzazioni internazionali che trattano di problemi ambientali. La delocalizzazione progressiva degli insediamenti minori e delle varie infrastrutture è l'unica garanzia della sostenibilità sul lungo termine di qualsiasi intervento. Ovviamente non tutto potrà essere delocalizzato, e qui non si potrà rinunciare alla difesa ad oltranza. L'arretramento non è però sinonimo di abbandono: lo spazio costiero andrà riprogettato, sviluppando funzioni alternative a quelle attuali e con investimenti adeguati, eventualmente superiori, sull'immediato, a quelli necessari per la difesa tradizionale.

La scelta della strategia da adottare è resa ancor più difficile dall'incertezza degli scenari che siamo in grado di prevedere. Non solo di quelli fisici: ad esempio di quanto s'innalzerà il livello del mare o quale sarà l'intensità delle mareggiate con il clima futuro, ma anche di quelli socio-economici e tecnici.

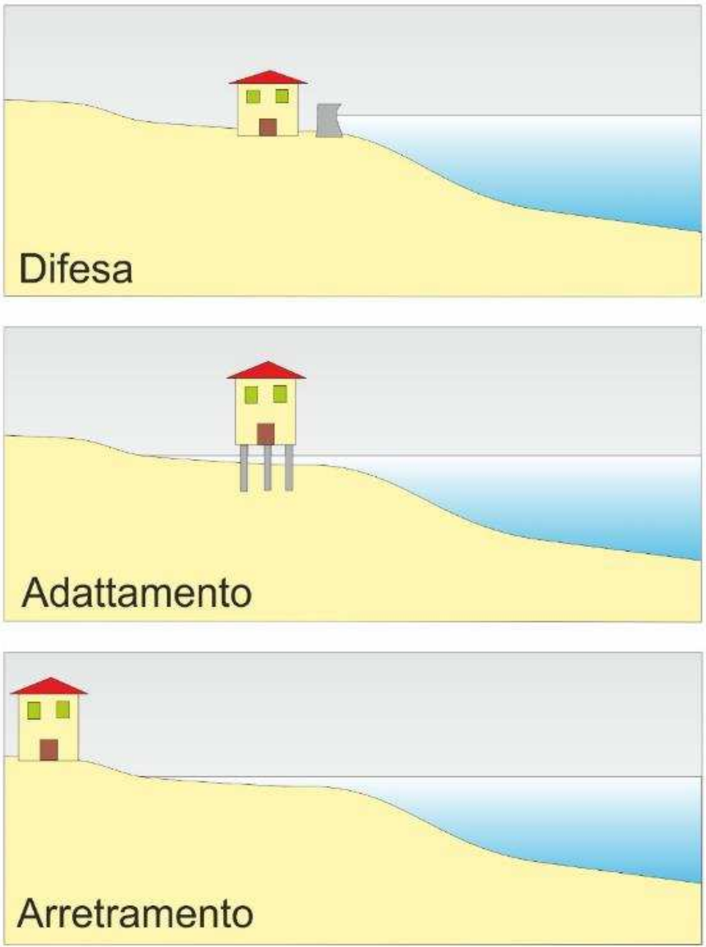

Figura 2. Le diverse strategie che si possono adottare per fare fronte all'innalzamento del livello del mare e all'erosione costiera. In alcuni casi una strategia mista può essere quella più opportuna.

Il valore delle strutture attuali è facilmente calcolabile, ma quale sarà il loro valore fra alcuni decenni? Per rimanere sul problema delle spiagge: saranno esse ugualmente appetibili con temperature estive più alte? E più che altro, il turismo internazionale sceglierà altre destinazioni? A ciò si aggiunge l'incertezza politica dei paesi che ospitano altre destinazioni turistiche, che ha favorito la crescita del settore turistico-balneare negli ultimi anni, ma che speriamo possa ridursi in un prossimo futuro.
Tutto ciò costituisce un'incredibile sfida per il mondo scientifico, sia per lo sviluppo di migliori modelli per la previsione degli scenari futuri, sia per quello di soluzioni tecniche innovative, che garantiscano la resilienza del sistema costiero e la possibilità di sviluppo socio-economico delle comunità che vivono in questa fascia di territorio.
Tutto ciò accresce l'incertezza nella quale ci dobbiamo muovere oggi, dato che le soluzioni tecniche un domani disponibili potrebbero rendere possibile quello che oggi appare impossibile, senza lasciare in eredità alle generazioni future una situazione ambientale insostenibile.
Il problema principale non è però tecnico o economico, bensì politico: soluzioni sostenibili sul lungo periodo hanno costi, in termini di consenso, difficilmente accettabili in un sistema che richiede successi immediati, seppur effimeri. La crescita culturale diventa quindi un requisito essenziale per consentire scelte che garantiscano l'equità trans-generazionale. Questo non riguarda solo il problema dell'erosione costiera, ma anche tutte le altre problematiche, assai più rilevati, che coinvolgono l'intera popolazione del nostro pianeta.

Pressione antropica sulle coste italiane

Antonio GOLINI (Linceo, Sapienza Università di Roma) - Stefano TERSIGNI (ISTAT, Roma)

La penisola italiana con una lunghezza litoranea di 8.700 chilometri è uno dei paesi europei con il maggiore sviluppo costiero del proprio territorio.

Nelle 15 regioni bagnate dal mare, 644 comuni si collocano lungo la fascia costiera, ovvero l'8,1 per cento dei comuni italiani, estesi su una superficie complessiva pari al 14,3 per cento della superficie nazionale, su cui insiste il 28,4 per cento della popolazione residente in Italia (dati riferiti al 31/12/2017). Le aree litoranee risultano quelle più densamente popolate: in media 400 abitanti per chilometro quadrato, rispetto ai 168 delle aree non litoranee.

La Campania, il Lazio e la Liguria sono le regioni con la più alta densità di popolazione litoranea, rispettivamente con 1.233, 1.041 e 948 abitanti per chilometro quadrato.

Nel Mezzogiorno, la superficie territoriale litoranea supera i 30 chilometri quadrati (70,8 per cento), mentre la popolazione residente (9.548.059 unità) rappresenta il 55,6 per cento di tutta la popolazione litoranea.

Dei 644 comuni, circa più di un terzo sono localizzati in Calabria e Sicilia (37 per cento). Per quanto riguarda gli abitanti residenti la regione con la maggiore popolazione è il Lazio (soprattutto per la presenza del comune di Roma), seguito da Sicilia e Campania.

In particolare in questi comuni va segnalato, esaminando i dati dei censimenti decennali della popolazione, un incremento della popolazione, nel trentennio 1951 – 1981, dal 26,4 per cento al 29,9; in termini assoluti un aumento di circa 4,4 milioni di unità. A partire dal 1991 si osserva una leggera riduzione degli abitanti fino ai 16.674.536 (28 per cento) del 2011.

La presenza lungo le coste di importanti città (9 capoluoghi delle 15 regioni bagnate dal mare sono comuni litoranei) e di grossi centri non basta da sola a spiegare il fenomeno dell'incremento demografico. Altri fattori hanno rivestito un ruolo fondamentale: da un lato l'inesorabile declino economico degli insediamenti rurali delle aree interne dall'altro, il sorgere di infrastrutture industriali lungo le coste e lo sviluppo turistico, talvolta selvaggio, di molti tratti del nostro litorale. L'incremento si è stabilizzato e parzialmente ridotto a partire dall'inizio degli anni '90 anche a causa della crisi dei grandi poli industriali.

Per quanto riguarda le attività produttive in questi 644 comuni si registra la presenza di più del 28 per cento di tutte le unità locali, produttive o amministrative, del Paese. In tali unità opera il 26 per cento di tutti gli addetti nelle imprese.

La forte urbanizzazione, il turismo, le attività industriali producono una forte pressione ambientali su questi territori, che possiamo misurare, oltre che con la popolazione e le attività economiche presenti, anche con altri indicatori, prodotti dalla statistica ufficiale, che riguardano i carichi inquinanti prodotti, la depurazione delle acque reflue, i consumi di acqua potabile, la presenza turistica, la qualità delle acque di balneazione, le attività estrattive da cave e miniere.

Onde sotto costa: correnti ed interazioni con le opere di difesa

Pier Luigi AMINTI (GNRAC - Università di Firenze)

Le onde di mare che si propagano in acque profonde non danno origine a trasporto di massa e quindi non generano correnti; il loro studio può essere svolto indipendentemente dalle interazioni col fondo purché la profondità sia superiore alla metà della lunghezza d'onda. La loro lunghezza d'onda è funzione solo del periodo. Quando le onde si propagano in acque basse la lunghezza d'onda è influenzata dalla profondità ed anche l'altezza d'onda aumenta (shoaling) fino a raggiungere una condizione di instabilità che culmina col frangimento e la rottura dell'onda.

La fascia di spiaggia compresa fra la linea dove inizia il frangimento e la linea sulla spiaggia dove arriva la risalita delle onde è interessata dai fenomeni indotti dalla dissipazione dell'energia delle onde.

L'interazione delle onde con il fondo genera fenomeni di rifrazione che, su fondali a debole pendenza e forma planimetrica regolare, come lunghi tratti di spiaggia quasi rettilinei, provocano la rotazione dei fronti d'onda che tendono a disporsi paralleli alla linea di riva

Quando le onde frangono con fronti non paralleli alla linea di riva si origina una corrente che interessa tutta la zona dei frangenti (surf zone) che induce anche un trasporto dei sedimenti sciolti presenti sul fondo.

Nel caso in cui su un tratto di costa l'uscita dei sedimenti non sia compensata da un ugual volume di apporti, in genere da parte dei fiumi, si verifica un arretramento della linea di riva che è l'indicatore più evidente del fenomeno noto come erosione costiera, ormai generalizzato su gran parte delle coste italiane.

I fenomeni erosivi si manifestano in un primo tempo solo in presenza di mareggiate eccezionali e quindi piuttosto raramente, ma se non viene invertita la tendenza, tali fenomeni diventano sempre più frequenti e riducendosi l'ampiezza della spiaggia in grado di assorbire l'energia delle onde, vengono esposte all'attacco delle mareggiate le opere e le infrastrutture costruite lungo le coste, con i danni conseguenti.

È a questo punto che vengono costruite opere di difesa della costa, ed i processi di interazione fra onde, correnti e sedimenti presenti su spiagge naturali, vengono modificati dai processi di interazione fra onde, correnti opere di difesa e sedimenti.

La maggior parte delle opere di difesa sono state costruite con barriere parallele a riva intervallate da varchi per garantire un adeguato livello di ricircolo delle acque nella zona protetta, oppure vengono utilizzate scogliere sommerse per permettere una migliore circolazione e ridurre l'impatto visivo delle difese.

Le opere in generale arrestano l'arretramento della linea di riva e vengono percepite come opere risolutive, perchè permettono il mantenimento delle superfici di spiaggia utilizzate per il turismo estivo e per mantenere in sicurezza gli abitati costieri.

Il sistema di correnti litoraneo risulta nettamente modificato rispetto a quello presente su spiagge naturali, ma a fronte di una riduzione degli effetti sulle zone protette, vengono accelerati i fenomeni erosivi e le modifiche morfologiche sui litorali esterni alle opere di difesa e sui litorali vicini.

Ad esempio le barriere parallele se provocano sedimentazione nella zona protetta inducono una riduzione della velocità della corrente lungo riva dietro di esse ma ciò fa aumentare la velocità nella zona non protetta e conseguentemente incrementare la capacità di trasporto delle onde esternamente al sistema di difesa. (Tab.1 figure in alto). Sommando gli effetti delle onde riflesse dalle barriere, nel tempo si ha un approfondimento dei fondali esterni ed una modifica irreversibile della forma del profilo (Tab1 Figure in basso).

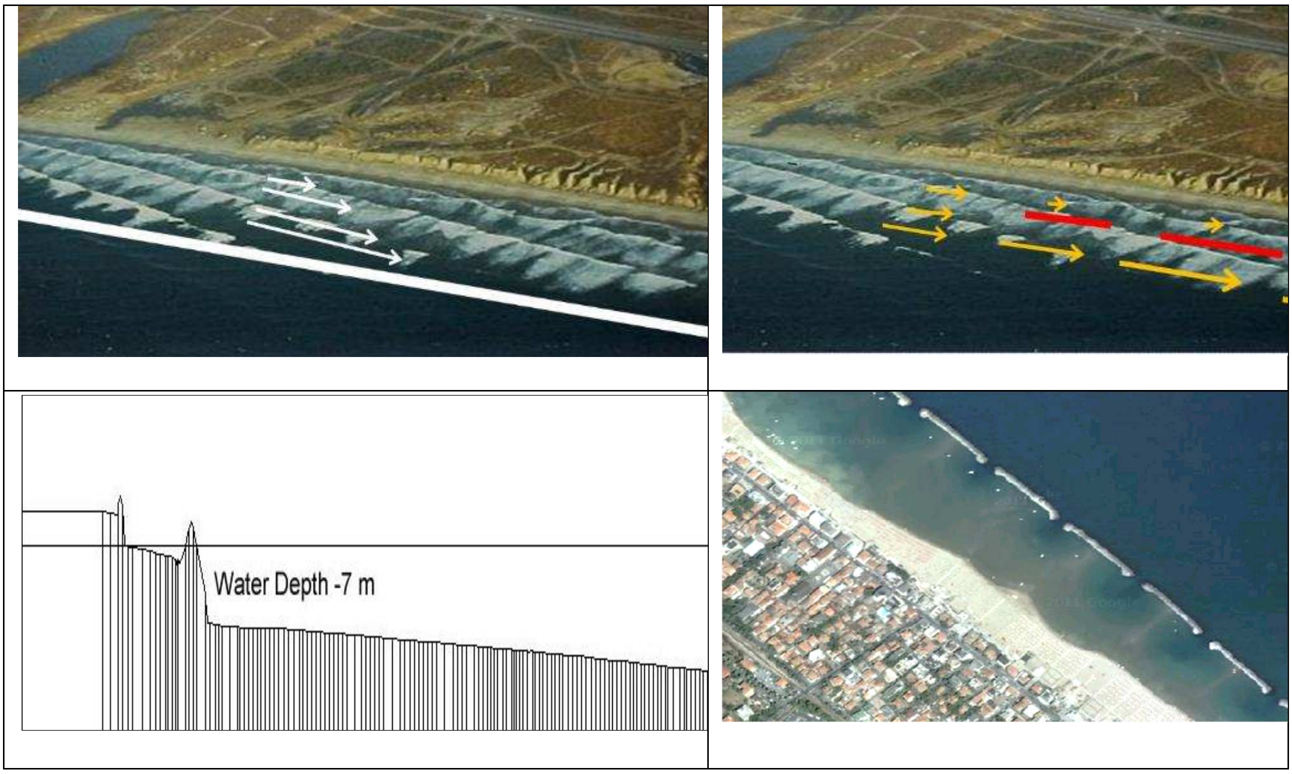

Fig. 1 variazioni indotte da barriere parallele al campo di correnti e alla morfologia delle spiagge

Complessivamente con difese parallele a riva si ottiene una stabilizzazione della linea di riva ma anche un contemporaneo approfondimento dei fondali al largo delle difese che dovranno essere rafforzate fino a quando non viene raggiunta una nuova situazione di equilibrio in cui la presenza di opere efficienti diventa fondamentale per il mantenimento delle spiagge. Con le opere sommerse, o emerse ma con cresta bassa quindi tracimabili, durante una mareggiata si ha un incremento del livello idrico medio nella zona protetta rispetto al livello esterno. quindi a fronte di una riduzione degli effetti indotti dall'impatto delle onde, vengono accentuati i fenomeni indotti dalla presenza delle correnti generate dal sovralzo che possono rendere meno efficienti le difese e meno sicure le spiagge protette con questa tipologia di opere

Nei casi in cui il trasporto litoraneo abbia un verso nettamente dominante vengono costruite difese basate su pennelli ortogonali a riva allo scopo di annullare o almeno ridurre significativamente lo spostamento di sedimenti lungo riva.

Anche queste opere in genere raggiungono lo scopo di stabilizzare la linea di riva o di creare zone di avanzamento ma una volta che si è raggiunta una nuova forma di equilibrio per la linea di costa la circolazione litoranea viene modificata e complessivamente si ha un minore apporto di sedimenti verso le zone sottoflutto agli interventi realizzati.

Fig. 2 Variazioni indotte da barriere parallele al campo di correnti e alla morfologia delle spiagge

Tecniche di difesa costiera e cambiamenti climatici

Enrico FOTI (Università di Catania)

Le coste italiane sono soggette ad elevato rischio di erosione e inondazione, imputabile sia alla considerevole densità abitativa, che determina una grande esposizione, sia alle caratteristiche morfodinamiche di tali aree, che comportano un notevole fattore di pericolosità. In particolare, l'erosione costiera è dovuta all'azione che onde e correnti esercitano sulla spiaggia ed è accentuata dalle alterazioni antropiche del trasporto solido sia fluviale che litoraneo. Per quanto concerne il rischio di inondazione costiera, esso è legato al verificarsi di eventi marini eccezionali ed interessa particolarmente quelle aree in cui sono rilevanti i fenomeni di subsidenza ed eustatismo.

Tradizionalmente, la protezione della costa è operata mediante la realizzazione di opere. Le difese passive producono un'attenuazione dell'energia del moto ondoso incidente, mentre le difese attive producono anche un incremento localizzato della spiaggia. La metodologia utilizzata per la progettazione di tali opere consiste nella stima delle condizioni di progetto relative ad un fissato tempo di ritorno tramite l'analisi statistica di dati meteo-marini storici registrati presso il sito di interesse. Tuttavia, tale approccio è messo in crisi dalla mancanza di una rete di monitoraggio delle grandezze meteo-marine su scala nazionale e dalla non stazionarietà dei fenomeni naturali legata ai cambiamenti climatici, i cui principali effetti sono l'innalzamento del livello medio del mare, l'incremento della frequenza di accadimento di eventi estremi e la maggiore severità delle forzanti.

Alla luce degli effetti dei cambiamenti climatici, la mitigazione del rischio costiero deve essere realizzata attraverso misure istituzionali di ricollocazione e gestione delle attività sul territorio, prevedendo lo sviluppo di sistemi di monitoraggio e preallerta. Per quanto concerne le opere di difesa, per prima cosa è necessario pensare ad un adeguamento delle strutture esistenti, laddove tale intervento possa risultare tecnicamente ed economicamente conveniente. È, inoltre, possibile progettare degli interventi resilienti che si adattino in modo naturale alle mutevoli condizioni ambientali. Infine, negli ultimi anni sono stati sviluppati dei progetti basati sull'integrazione di tecniche tradizionali e innovative che mirano alla realizzazione di sistemi non semplicemente resilienti, ma antifragili.

Evidenze geologiche di tsunami sulle coste del Mediterraneo

Giuseppe MASTRONUZZI (Università di Bari)

Il bacino del Mediterraneo è caratterizzato da un'articolata linea di costa il cui andamento deriva dalla complessità della storia geologica degli ultimi milioni di anni. Catene montuose e piane abissali disegnano, in un'area relativamente poco estesa, un paesaggio che è estremamente energetico tanto rispetto ai processi endogeni che ne dettano la geodinamica tanto a processi esogeni che complicano la dinamica delle forme del paesaggio. La recente surrezione delle catene montuose perimediterranee e il perdurare di una complessa dinamica relativa fra la placca africana e quella euroasiatica individuano una rete di bacini abissali in espansione, di aree di subduzione e di aree di collisione in sollevamento marcati dalla diffusa presenza di vulcanismo a diverso grado di parossismo in un contesto geodinamico ad elevata sismicità (Anzidei et al., 2014).

A rendere la geografia ancora più complessa è la brevissima distanza che intercorre fra piane abissali profonde sino a più di 5000 m e catene montuose rilevate sino a 2000 m fra loro separati da poco estese piattaforme continentali, peraltro caratterizzate da imponenti ed instabili spessori di sedimenti accumulati negli ultimi cicli climatici che tanto hanno segnato la morfografia del bacino del Mediterraneo (Mastronuzzi , 2010).

Insieme, vulcanismo sottomarino e costiero, elevata sismicità tettonica, instabilità delle aree montuose costiere e delle estese scarpate continentali rispetto ai processi gravitativi indotti da una sismicità elevata, definiscono un quadro in cui la probabilità che si generi uno tsunami anche come conseguenza di una sequenza di eventi ad "effetto domino" è elevata. A definire per il bacino del Mediterraneo un quadro di alto grado di rischio da impatto di tsunami contribuiscono: ì – la diffusa presenza di evidenze di impatto di tsunami manifestatisi nel passato; ìì – le ridotte distanze fra possibili aree tsunamogeniche e la linea di costa; ìì - l'elevato grado di urbanizzazione della fascia costiera che nel tempo ha definito un'elevata concentrazione di siti residenziali ad alta densità di popolazione, di aree produttive e strategiche, di emergenze culturali e paesaggistiche. Tali fattori corrispondono alle tre componenti del rischio, rispettivamente la pericolosità, la vulnerabilità e il valore.

A definire il primo contribuiscono dati che derivano dall'analisi storica, archeologica ed archivistica che ha permesso di costruire i primi cataloghi di tsunami per il Mediterraneo (Soloviev *et al.*, 2000; Tinti *et al.*, 2004; 2007; Guidoboni & Comastri, 2007). Lo studio di tali dati non solo ha permesso di individuare l'evento ma ha anche, con diversi gradi di approssimazione, di definire i danni in termini di vite umane. Lo tsunami generato dal sollevamento cosismico che accompagnò il terremoto di Creta del 365 d.C. (Ammiano Marcellino, Res Gestae, 26.10.15-19) sembra abbia causato circa 50mila vittime lungo il Delta del Nilo; gli tsunami che hanno colpito la costa orientale della Sicilia nel 1169 d.C. e nel 1693 d.C. si stima abbiano fatto circa 20mila e 60mila vittime rispettivamente.

Se la quantificazione del valore deriva da un approccio multidisciplinare per definire il peso tutti i contributi sociali, nella definizione dei primi due fattori ha ruolo essenziale l'analisi della fascia costiera dal punto di vista geologico. L'individuazione di evidenze geomorfologiche e sedimentologiche permette infatti di definire con approccio deterministico la frequenza con la quale l'evento si manifesta e l'estensione dell'area colpita dai singoli eventi.

Purtroppo le evidenze geomorfologiche dell'impatto di ondazioni eccezionali sulla costa sono differenti e non sempre di facile interpretazione e correlazione all'azione di *tsunami*; (Mastronuzzi e Sansò, 2004; Mastronuzzi et al., 2010; 2013). Lungo le coste dell'Italia meridionale, ed in particolare in Sicilia e in Puglia, le evidenze geomorfologiche correlabili con gli eventi di *tsunami* sono rappresentate da ventagli di rotta, accumuli di blocchi di grosse dimensioni provenienti dall'ambiente sommerso o da quello immediatamente adlitorale, sottili livelli sedimentari di alta energia impilati in depositi costieri. In molti casi l'attribuzione definitiva all'impatto di *tsunami* di forme e sedimenti è stato possibile solo grazie alla correlazione con dati archeologici e fonti storico-archivistiche (Scicchitano *et al.*, 2007; Mastronuzzi & Pignatelli, 2012).

In Puglia, nel Lago di Lesina, sono presenti tre grandi ventagli di rotta (Gianfreda *et al.*, 2001). Ognuno di essi è stato generato da un veloce flusso d'acqua e sedimenti che ha attraversato il cordone litorale in corrispondenza delle debolezze strutturali nel locale basamento argilloso dovute al terremoto che lo aveva generato. Grazie ai principi della morfostratigrafia, a datazioni AMS e a dati storici è possibile qui riconoscere l'impatto di tre tsunami avvenuti (ì) in età Pre-Romana 736 a.C. circa, (ìì) nel 493 a.D. correlato al forte terremoto che colpì il promontorio del Gargano, riportato anche in alcuni documenti medievali (Piccardi, 2005), e, infine, (ììì) il 30 luglio 1627 che colpì buona parte della costa settentrionale del Gargano (Mastronuzzi & Sansò, 2012).

Lungo la costa sud-orientale della Puglia è stata riconosciuta una delle più estese ed evidenti tracce di impatto di *tsunami*. Presso Torre Sant'Emiliano, a sud di Otranto, è presente un accumulo di blocchi di dimensioni sino a circa 70 tonnellate per una lunghezza di circa 1.5 km disposti a formare una berma di morfologia complessa che raggiunge la quota massima di circa 11 m s.l.m. L'articolazione della berma suggerisce che essa sia stata accumulata da due successive onde che in rapida sequenza avrebbero impattato lungo costa provenendo da SSE. Dati geocronologici, confermati da dati archeologici, suggeriscono un accumulo manifestatosi circa 300 anni fa. I cataloghi disponibili indicano il sisma del 20 febbraio 1743 quale più probabile evento responsabile della genesi di uno *tsunami* (Mastronuzzi *et al.*, 2007).

La costa della Sicilia Orientale è quella che per conformazione degli ambienti costieri e per esposizione alle aree sismogeniche e tsunamogeniche del mare Ionio ha restituito la maggior quantità di evidenze dell'impatto di *tsunami*. Grandi quantità di blocchi distribuiti da Augusta sino a Capo Passero sono stati attribuiti tanto all'impatto di *tsunami* quanto all'impatto di mareggiate estremamente potenti (p.es.: Scicchitano *et al.*, 2007; Barbano *et al.*, 2010). Le aree umide costiere della Sicilia sudorientale, inoltre, costituiscono delle ottime "trappole" sedimentarie; in queste e nelle aree di piattaforma continentale ad esse adiacenti studi condotti dall'INGV (Istituto Nazionale di Geofisica e Vulcanologia) hanno permesso di riconoscere livelli di depositi schiettamente marini intercalati nella normale sedimentazione degli ambienti umidi costieri così come hanno permesso di individuare livelli anomali, con caratteri di deposizione energetica, intercalati nei depositi di piattaforma *off-shore* (Gerardi *et al.*, 2012; De Martini *et al.*, 2012; Smedile *et al.*, 2011). L'area forse maggiormente significativa è quella di Pantano Morghella, subito a nord di Capo Passero. Sondaggi qui terebrati hanno restituito evidenze di deposizione di almeno due profonde inondazioni conseguenti alla penetrazione di *tsunami* nell'entroterra avvenute sulla costa ionica della Sicilia. Comparando i risultati delle datazioni al carbonio e datazioni OSL con i cataloghi degli *tsunami*, sembra che i due depositi sabbiosi anomali siano attribuibili allo *tsunami* di Creta del 365 d.C. e, probabilmente allo *tsunami* del 1908. Nell'area di Augusta, sondaggi sulla piattaforma continentale hanno messo in evidenza più livelli anomali che sono interpretati quali testimonianze dell'impatto di *tsunami* avvenuti nel 365 a.C. nel 1169, nel 1693 e nel 1908 d.C.

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Comunicazioni

Monitoring, risk forecasting and coastal planning in the Region of Tuscany

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Introduction

Coastal zone management, including the planning of structural and non-structural interventions in order to defend the coast, needs the adoption of decision supporting tools such as coastal monitoring systems, also aimed at understanding the effects caused by the joint actions of sea waves and land-sea interactions. In the context of global change, it is particularly important to understand which signs of climatic evolution can have significant impacts, for example in the loss of coastal areas as a result of coastal erosion, sea level rise and urbanization (coastal squeeze).

The Region of Tuscany, with the regional law *LR 80/2015* has defined a tool for coastal management, in accordance with the national guidelines (MATTM-Regioni, 2018). This law distinguishes two different monitoring activities (*'Linee guida sulle attività di monitoraggio della costa'*, *DGR 1069/2018*[1]): at a local scale and at regional level. The latter is an important innovation, as it establishes that even at regional level, coastal sediments budget should be evaluated every year. Regional scale monitoring requires spatial scales of the order of tens to hundreds kilometers with spatial resolutions possibly lower than one meter, and it can be sustainable provided that remote monitoring is used as the main database. In this way, monitoring activity assumes an operational value, which can be better understood in association with the monitoring of physical parameters such as winds, waves and currents that contribute to coastal morpho-dynamics. In addition, it was also requested to develop: 1) an *in-situ* observing network, carried out through a combined system of offshore and coastal buoys, operational since 2008, and 2) a modeling activity in order to analyze and forecast the sea state along the coast, taking into account available measurements, able to extend the validity of observations along the Tuscany coast.

Observation activities at regional scale, monitoring and wind/wave modeling are carried out by the Region of Tuscany in synergy with the LaMMA Consortium.

As for the surveys at local scale, these are carried out using both traditional methods and the increasing use of detection platforms such as UAV drones, terrestrial and/or aerial lidar technologies.

The availability of such data and technical tools is fundamental in order to support several needs for Integrated Coastal Zone Management activities, such as coastal monitoring, coastal planning and risk management at short-term and long-term timescales.

These activities are described below in relation to the recent case of the coastal storm dated 28-30 October 2018; in addition, some considerations regarding the methodologies to be adopted, for coastal monitoring and the planning of interventions along the coast are illustrated, in particularly in relation to present climate change rates.

Coastal risk assessment: a recent case study

Coastal risk forecasting / management activities should be defined in relation to time scales of interest. Short-term risk assessment refers to the identification, forecasting and management of the risk associated with the impact of severe sea storms along the coast, with particular reference to extreme events.

On the other hand, long-term risk refers to long-term coastal erosion processes that can lead to the loss of natural or urbanized coastal environments. In the first case, the reference technical tool is represented by weather and wave forecasting models, together with available observations from *in-situ* measurement instruments. In the second case, it is necessary to consider long-term wind and wave climate, not limited to the knowledge of the trend measured in the last decades, in order to take into account the most reliable scenarios

[1] http://www301.regione.toscana.it/bancadati/atti/DettaglioAttiG.xml?codprat=2018DG00000001323

of global change.

In order to assess the impact of climate change along the coast, great attention has been paid, in the past, to sea level rise scenarios while only a few studies are dedicated to assessing the potential impact along the coast due to the changes of circulation regimes.

A relative increase in the frequency of events from the southern quadrants compared to the northern ones has been observed in several European areas, also in relation to the impact of the wave climate along the coast (Thomas *et al*., 2010).

Similar variations have been observed in the Mediterranean as well. In the Northern Mediterranean Sea, for example, many data and monitoring activities, suggest a relative increase in the frequency of south-easterly winds and seas ('*Scirocco*') and a relative decrease in north-westerly flow ('*Maestrale*'), with possible consequences on the morpho-dynamic balance of several coastal sites (E. Pranzini pers. com.)

Extreme events from S-SE, rather than events from SW associated with perturbations of Atlantic origin, change, in some cases, criteria and design parameters of coastal defense works. These potential long-term wind and wave climate trends can have consequences not only in the assessment of long-term risk, induced to the main morpho-dynamic variations of the coast with shoreline erosion, but also in short-term risk assessments, related to the impact of sea storms along the coast.

A recent example is the storm occurred at the end of October 2018, whose impact has been destructive along many shores of the North-Western Mediterranean. In fact, around the 28th-31st October 2018 the coasts of the North-Western Mediterranean in particular of the North Tyrrhenian and Ligurian Seas were hit by a storm event with exceptional characteristics and a huge and destructive impact along the coast of Tuscany and Liguria. Several beaches, coastal structures and harbors have been damaged by this event, the exceptionality of which mainly concerns the direction of the prevailing sea, in this case from the south and south-east more than the south-west that is by far more common in this area (coastal morphology is consequently "adapted" to this). The storm event was very important along the Tuscan coast which has a large number of sandy beaches, and in which approximately 30 kilometers experienced heavy damage; also along neighboring Ligurian coast the event had an even greater impact because of the superposition of winds from the south and the southwest.

The costal areas more heavily damaged from this storm were those more directly exposed to the waves from SE ('*Scirocco*'). The impact of such waves was amplified by the high sea level stand (surge) due to a deep low atmospheric pressure in the Ligurian Sea that favored a higher wave run-up along several beaches (for example, in the Follonica Gulf in Tuscany).

In order to verify the existence of dangerous conditions for public safety and to fully assess the effects of the storm, UAV surveys, bathymetric surveys and Side Scan Sonar seafloor mapping were performed along approximately 34 km of the Tuscany Region coast during less than 45 days after the storm event.

The results of these surveys made it possible to evaluate the impact of the storm on the beach profile highlighting in particular a widespread erosion in the shore-face with consequently a shift of sediments towards greater depths in the near-shore area (*Fig. 1*). A general retreat of the shore-line and a lowering of the beach volume up to the foot of the dune ridge was also found.

On the basis of these monitoring activities, a master plan for coastal interventions has been drawn up, aimed at restoring the morpho-sedimentary conditions of the beaches as modified by the weather event, identifying specific actions for each coastal area under examination.

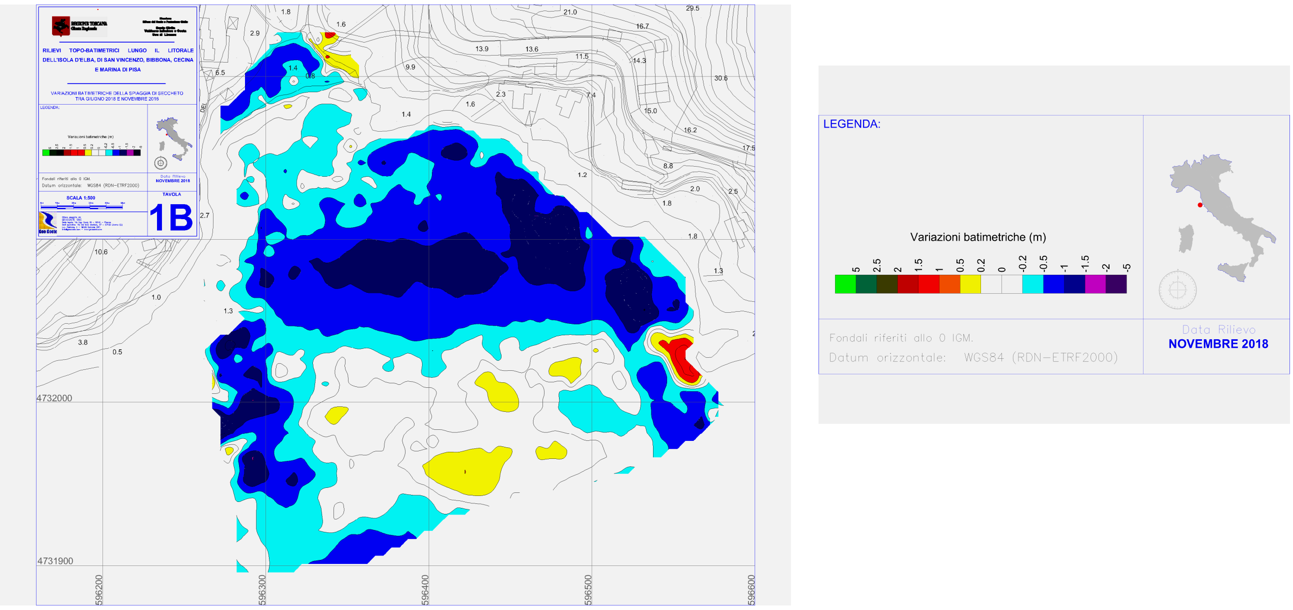

Fig. 1 Example of overlapped topo-bathymetric map “pre and after storm event” at Seccheto beach - Elba Island (Region of Tuscany)

Although this storm event was so intense, it was observed that a similar situation with many common characteristics occurred, for example, on November 6th 2000, thus less than 20 years ago, which hit the same coastal areas causing, among other things, very similar effects such as coastal dune over-wash in Follonica and the collapse of the breakwater of the Marina at Rapallo in Liguria.

Many coastal defenses and marinas/ports were in fact designed on the basis of wave and wind climate derived from data recorded by large national networks that, in the recent years, not always guaranteed the necessary continuity of the registrations in order to develop sufficiently reliable long-term statistics.

Definition of coastal climate for coastal planning

The design parameters of coastal structures were elaborated taking into account that the prevailing wind and sea conditions are those from south-west as this wind ('*Libeccio*') in the north-west Mediterranean has various configurations associated with more or less extensive circulation, depending on the baric configurations. The exceptional nature of these events therefore is not only due to the intensity of the sea-storms, but also by the wind/wave direction associated with particular atmospheric circulation.

It is very important to determine if the frequency with which this type of events occur is greater than in the past. We believe that potential climatic variations linked to changes in the wind/wave regime, and their impact, must be studied in a much more detailed way compared to what has been done so far, because they can profoundly change the way in which the coast is protected, including the design parameters of coastal structures.

The impact of climate change along the coast does not only concern the long-term trend of beach erosion, but also the way in which extreme phenomena occur, and the magnitude of their destructive potential. For what concerns coastal environment restoration, coastal planning can be done with the aim to restore/replenish coastal areas damaged by a particularly intense event or by a series of such events.

The economic value of the coastal areas in Tuscany largely justifies these choices. However, with regard to coastal defense interventions, protection strategies should also be based on considerations regarding the long-term evolution of the coastline and not focusing on a single event, however destructive.

Coastal restoration planning at regional scale in Tuscany develops from the frequent updating of the coastal state and in particular of the short and long-term evolutionary trends, in order to monitor both the critical spots along the shore-line and the coastal zone sedimentary budget. In addition, the evaluation of the sediment balance for each coastal cell allows to identify near-shore sediment sources which represent Strategic Sediment Reservoirs for coastal restoration works (amounts of sediment of “appropriate” characteristics that are kept available for future replenishment of the coastal zone – EUROSION, 2007). In this scenario it is evident the importance of the continuous coastal zone monitoring and the contribution offered to a correct understanding of the dynamics from an accurate knowledge of coastal climatology.

Tools for a long-term coastal strategy

The Region of Tuscany has participated to many initiatives, such as EU funded projects, in order to share methods and best practices for coastal monitoring and the definition of strategies for the protection of coastal areas in the Mediterranean. At present, the MAREGOT project of the Italy-France Maritime cross-border Program (http://interreg-maritime.eu/web/maregot), presents a very broad set of activities including the analysis of short and long-term risks also in relation to climate change, the coastal sediment transport budget, the protection of rocky coastline and coastal ecosystems, the improvement of civil protection practices. Study methodologies are defined and applied to a number of test and pilot sites in the cross-border marine-coastal area which includes the coasts of Tuscany, Liguria, Sardinia, Corse and the Province of Var (PACA, FR). The analysis of risks related to storm events is carried out by the LaMMA Consortium, which is the technical partner of reference for the Region of Tuscany, thus implementing the activities of regional scale coastal monitoring defined by the *LR 80/2015.*

In particular, LaMMA is carrying out a high resolution coastal climatology over the entire North-Western Mediterranean area for the last 35-40 years, with the aim of:

1) to have a representative data set along the coast useful for the study of shoreline morpho-dynamics;
2) to use data for recent years in order to extract information on current climate change;
3) to improve the knowledge of coastal defense design data also in relation to climate change.

At a technical level, we use the reanalysis data of the latest ERA5 datasets available at ECMWF, from which we perform a higher resolution downscaling (about 3 km) with numerical atmospheric models such as WRF, BOLAM and MOLOCH. For wave hind-cast, the WW3 wave prediction model developed by NOAA is used. The latter has been operating at LaMMA for many years for operational wave forecasts, and it is now among the most consulted by users of meteorological services in the Mediterranean (www.lamma.rete.toscana.it). The specific model implemented for this activity uses an unstructured mesh which reaches 500 m near the coast and whose data are stored in the form of historical series, as synthetic data (Hs, Tp, Dm) and also spectra. Model data are calibrated and validated on the basis of all available information, in particular of all wave measurements available in the North-Western Mediterranean (including the regional network of the Region of Tuscany - www.cfr.toscana.it).

As an example, in Fig. 2 a map is shown with the operational wave forecast model for the 28-30 October 2018, and a very significant comparison between the wave model and the wave measurements at the Giannutri buoy of the Tuscany regional buoy network.

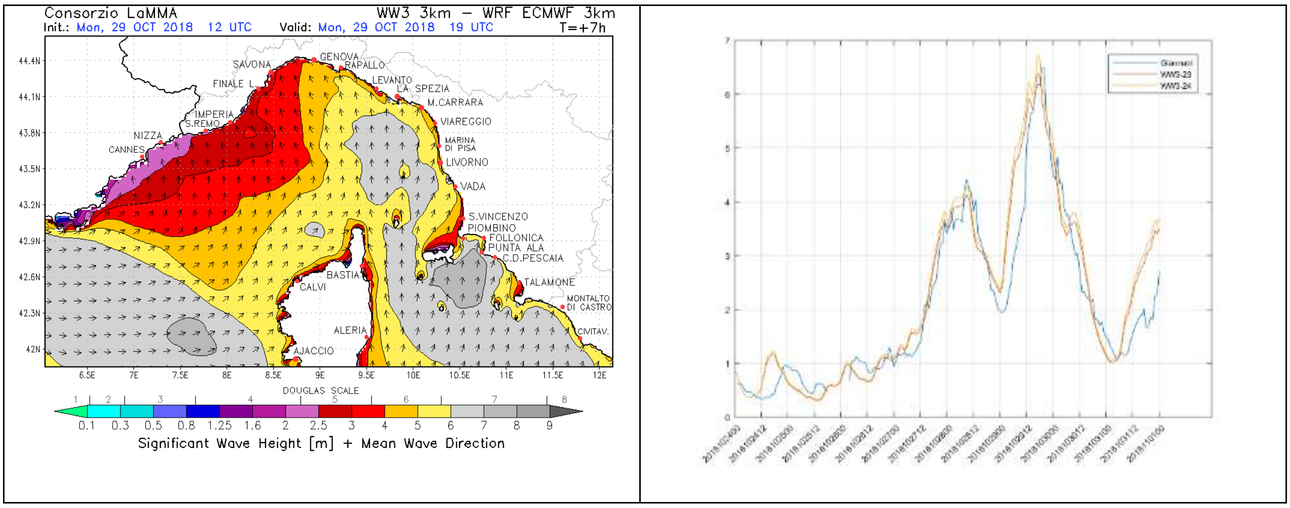

Fig. 2 Map of the LaMMA operational wave forecast model for the 29 October 2018 and comparison between model and observations at the buoy of Giannutri (Region of Tuscany)

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Multi-temporal analysis of dismantling coastal cliffs in the **Campi Flegrei** *volcanic area, Italy*

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Introduction

Many sea cliff sites worldwide are affected by retreat processes, mainly occurring through landslides, surface erosion and weathering (Trenhaile, 1987; Sunamura, 1992; Hampton and Griggs, 2004). In Italy, nearly 2,850 km of coasts are occupied by rocky shores and cliffs directly plunging into the sea, or separated from it by a thin strip of sandy/gravel beach or a reef of fallen blocks (Iadanza et al., 2009). Because of historical reasons and beauty of places, many coastal settlements were built along cliffed sectors where landslides represent a serious risk for living people, as well as for buildings, roads and railway networks.

The cliffed coastline of the Campi Flegrei volcanic area (Southern Italy), is among the most affected by dismantling processes. This is highlighted, for example, by the lacking of entire flanks of volcanic edifices formed in the last 5 ka, induced by both subaerial and marine processes (e.g., Capo Miseno and Nisida volcanos in Fig. 1). Generally, the massive retreat of volcaniclastic sea cliffs is promoted by weak mechanical properties and low resistance to erosion of the outcropping sediments (loose to welded ash, pumices, scoria), as well as by the local action of natural factors, such as sea waves, wind, rain, salt spray, wetting and drying cycles, changes in temperature and bioerosion. Many landslides occurred along the Campi Flegrei coastline in the past years. The Figure 2 shows two examples of tuffaceous cliffs affected by rock falls that caused sudden and localized recessions by displacing hundreds to thousands cubic meters of rocks.

Figure 1 - Aerial views of Nisida (left) and Capo Miseno (right) volcanic edifices. Images highlight as the original topography of both edifices was deeply modified by dismantling processes occurred in the last 5 ka (Images from www.panoramio.com).

Figure 2 - Typical rock falls affecting the Campi Flegrei coastal cliffs. (Credit for the image on the right: Alessandro Fedele, OV-INGV).

In the whole area, coastal landslides represent thus a serious threat for urban settlements built close to the edge of unstable cliffs, as well as for people that during the summer season lay on beaches at the base of them. The

Italian scientific community dedicated a moderate interest towards this topic, even if studies focusing on short- and long-term cliff retreat rates, as well as drivers controlling retreat mechanisms, are quite rare.

This paper presents results of the analysis and monitoring activities aimed at achieving a preliminary quantitative knowledge about retreat processes that are contributing to the geomorphic evolution of the Campi Flegrei rocky coast. The research is based on the use of geomatic techniques, and focuses on two representative coastal cliffs: “Torrefumo” and “Baia dei Porci” cliffs (Fig. 3). Both sites are located in the municipality of Monte di Procida, in the western sector of Campi Flegrei.

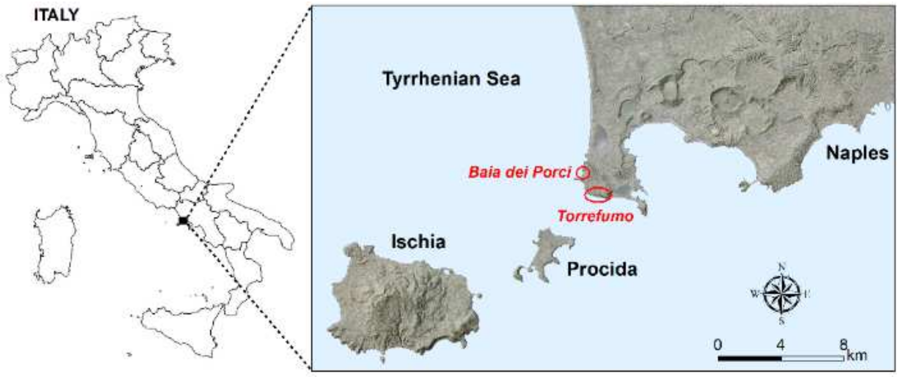

Figure 3 - Location of the Campi Flegrei volcanic area. Red circles highlight the two study sites.

Methodology

The mid-term geomorphic evolution of the Torrefumo cliff (years 1956, 1974 and 2008) was investigated by comparing digital elevation models (DEMs) derived from the processing of archive aerial images and airborne lidar data (ALS) (Esposito et al., 2018). This activity allowed quantifying volumetric changes, maximum retreat of the cliff top, and average retreat rates. The latters were calculated by applying the formula of Young and Ashford (2006) that takes into account the total eroded volume, the average sea cliff height and length.

The short-term geomorphic changes that affected part of this cliff, instead, were detected by comparing 3D point clouds acquired by terrestrial laser scanning (TLS) in two multi-temporal surveys (years 2013 and 2016). A cliff failures inventory map was developed and the magnitude-frequency distribution of the events was calculated. Further statistical analyses of the inventory data, together with field and topographic observations, showed that different geomorphic processes are contributing to the cliff retreat, and vary according to the outcropping lithotypes. The TLS-based analysis was also used to develop a cliff failure susceptibility model through the application of a bivariate statistical method (i.e. “Information Value” proposed by Yin and Yan, 1988), taking into account as predisposing factors the cliff height, average cliff slope, plan slope curvature, and profile slope curvature.

At the Baia dei Porci cliff site, a large rock slide occurred in October 2013 threatening a series of buildings located close to the cliff edge. The mass movement was monitored until January 2016 to assess its geomorphic evolution (Esposito et al., 2017). In this case, the “Structure-from-Motion” (SfM) photogrammetry technique was used and four surveys (years 2013, 2014, 2015, 2016) were executed from a boat and a remotely piloted aircraft system (RPAS). Moreover, a topographic survey of ground control points was carried out in order to guarantee the exterior orientation of images. Comparison of the 3D point clouds derived from the processing of photogrammetric data allowed accurate identification of the areas where geomorphic changes occurred, as well as quantifying volumes of material mobilized during and after the 2013 failure.

Results

Results of the change detection analysis related to the Torrefumo cliff (Fig. 4) highlighted that in the 1956-1974 time interval, a portion of 943,000 ± 28,000 m3 of cliff was eroded by retreat processes, whereas in the 1974-2008 analyzed time span, the amount of eroded cliff resulted in 220,000 ± 12,000 m3. These volumes allowed us to calculate two different retreat rates of 1.2 m/y and 0.17 m/y respectively (Esposito et al., 2018). The consistent difference between these two rates was interpreted as the consequence of a seawall construction occurred in the early 80’s to protect the entire cliff toe from the sea waves action.

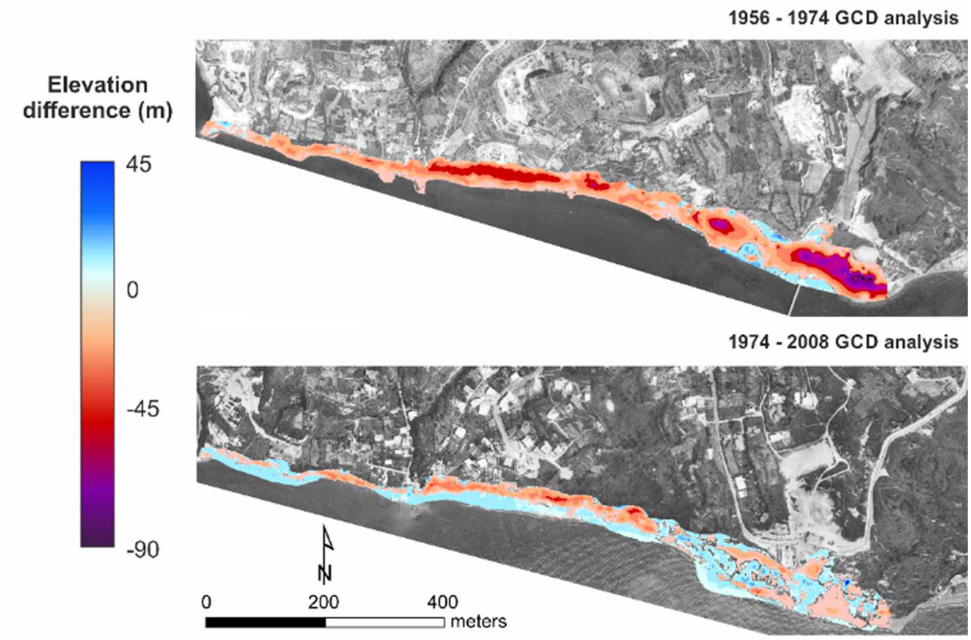

Figure 4 - DEMs of difference (DoDs) related to the Torrefumo cliff; negative elevation changes (reddish colors) highlight erosion, as well as positive changes (bluish colors) highlight deposition. Orthophotos of the year 1956 (above) and 1974 (below) are shown in background.

Short-term retreat rates, calculated by comparing TLS-derived 3D point clouds for different cliff sectors, ranged from 0.001 to 0.025 m/y, confirming that retreat processes are still continuing although the limitation of the sea wave action. TLS data also revealed that 191 cliff failures (Fig. 5) occurred in the 2013-2016 time interval. Statistical analysis of these failures showed that: i) the related magnitude-frequency distribution followed an inverse power law; ii) large events bigger than 100 m3 occurred rarely in the time span 2013-2016; iii) events between 10-2 m3 and 1 m3 were the most frequent, and the 90th percentile was equal to 2.35 m3; iv) types of instability processes varied over the cliff face and consisted in rock falls and grain-by-grain gradual erosion. Furthermore, field survey and further analyses of the 3D point clouds showed that a selective erosion is contributing to the cliff retreat, creating conditions for the triggering of block failures. The susceptibility analysis highlighted that 20% of the cliff face is still exposed to a high probability of failures, 15% to a moderate probability, and 65% to a low probability.

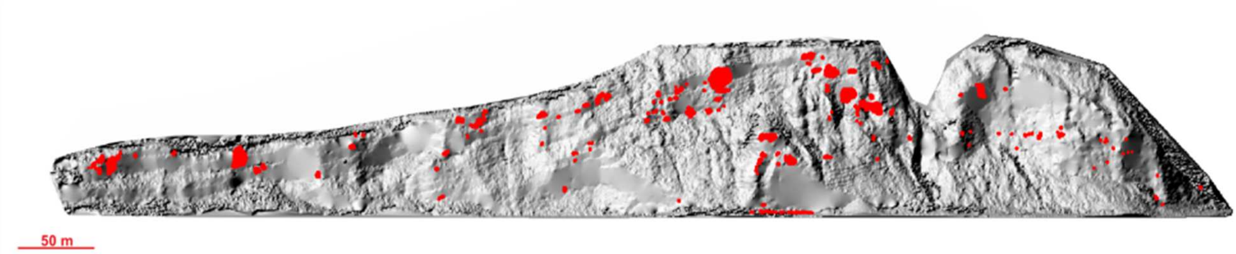

Figure 5 - Inventory of failures (in red) detected in the time span 2013-2016.

Monitoring activity of the landslide affecting the Baia dei Porci cliff site (Fig. 6) allowed calculating in about 40,000 m3 the volcaniclastic rocks displaced in the year 2013 major event, and in 5,000 m3 the material collapsed in secondary failures. Out of a total of 45,000 m3 of deposits accumulated at the base of the cliff, 29,000 m3 were eroded and only 16,000 m3 remained at the cliff toe at the end of the monitoring. A significant advantage of this type of multi-temporal monitoring consisted in the assessment of erosional patterns over time. The major scar erosion occurred, indeed, between the second and the third surveys (about one year apart), whereas deposit erosion mainly occurred between the first and second surveys (about three months apart). In cases like this, however, it could be also important to couple the geomorphic monitoring with weather and marine monitoring systems to understand environmental factors (such as storm surges or rainstorms) conditioning the landslide evolution.

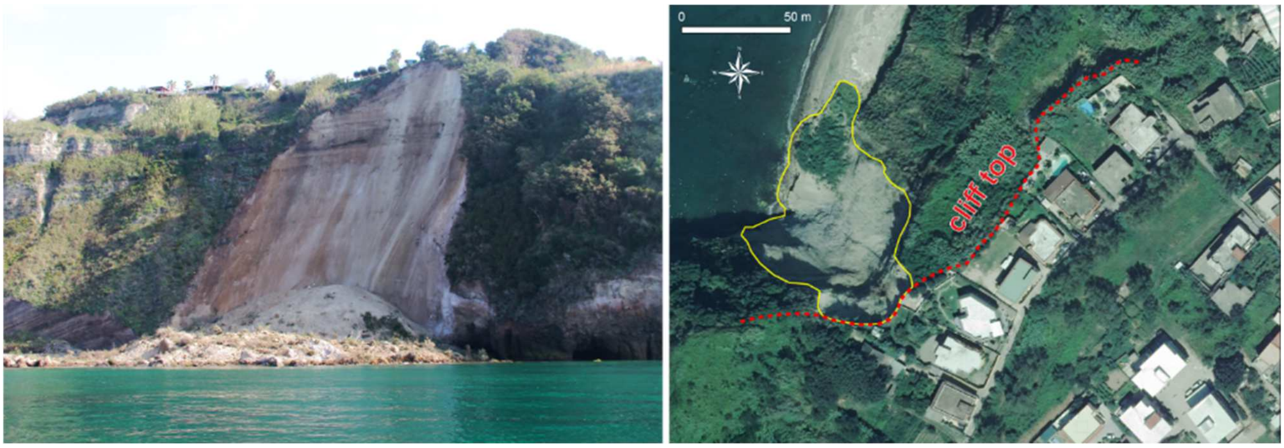

Figure 6 - Left: frontal image of the Baia dei Porci landslide acquired during the first photogrammetric survey. Right: 2014 aerial image (courtesy of the Campania Region) representing the landslide area (yellow continuous line) and the cliff top (red dashed line); it is worth noting the hazardous position of buildings close to the cliff top.

Conclusions

Results of this study highlight that mass wasting processes are effectively contributing to the dismantling of coastal cliffs in the Campi Flegrei volcanic area. Episodic cliff failures can displace huge masses of rock that induce sudden and localized cliff recessions, as for the Baia dei Porci cliff site. Notwithstanding, monitoring of the Torrefumo cliff performed by means of TLS showed that small-scale failures, between 10-2 m3 and 1 m3, are more frequent than larger collapses. The TLS-based monitoring activity also highlighted that failures are quite superficial and involve an average rock thickness lower than 1 m. This could be related to a general weakness of the surficial material induced by weathering processes, or by the occurrence of incoherent deposits of ash, pumices and scoria that are easy to be affected by grain-by-grain surface erosion.

Findings gained by the multi-temporal monitoring of the Baia dei Porci landslide demonstrated that after the main failure, landslide scars can be affected by further collapses, as well as deposits eventually formed at the cliff toe can be rapidly eroded by the sea wave action and, secondly, by rainfall-induced surface runoff. The sea wave action could be one of the most important drivers inducing retreat of cliffs in the the Campi Flegrei area, but additional accurate measurements are necessary to ascertain this. An indirect marker of the sea wave action is the massive retreat measured for the Torrefumo cliff (1.2 m/y), in the time period 1956-1974. Interruption of this action, after the seawall construction, induced a significant decrease of the cliff retreat rate to 0.17 m/y (1974-2008). On the other hand, it did not lead to a stable equilibrium condition of the slope, as testified by short-term retreat rates ranging from 0.001 to 0.025 m/y (2013-2016). The latters are comparable with retreat rates measured along the nearby Coroglio tuff cliff, ranging from 0.05 to 0.10 m/y, during the 2013-2015 time span (Caputo et al., 2018).

In summary, the described outcomes highlight that dismantling of the analyzed volcaniclastic coastal cliffs is due to a complex interaction of marine and subaerial processes. Some processes have been analyzed in this research but more studies need to be addressed for a complete knowledge of the cliffs behavior.

All the geomatic techniques applied in this study resulted suitable for monitoring, both from a logistical point of view and for the accuracy of obtained measurements with respect to the magnitude of investigated processes. Both survey techniques and methods used for data processing provided innovative solutions to improve accuracy of results, and to optimize the time-cost effectiveness with respect to the most common technologies used for monitoring coastal cliffs, and slopes in general. In order to assess evolution of cliff faces through time, further continuous or multi-temporal monitoring activities would be essential, as well as the use of oceanographic buoys and meteorological stations that could allow verifying eventual relationships between failures and environmental drivers, such as sea storms, rainstorms or cyclic thermal stress. Monitoring of the analyzed cliffs should be also useful for developing and calibrating numerical models aimed at predicting the cliffs evolution in risk assessment and reduction activities.

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Basilicata Ionian Coast: human and natural drivers of coastal dynamics

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1 Introduction

Tourism is worldwide recognized as one of the main economic drivers in coastal areas. It allows to enhance the generation of employment and constantly contributes to the economic incomes of these areas. The development of coastal tourism is highly dependent on the stability and the quality of the beaches (Yepes and Medina, 2005). As the matter of fact, this natural resource is rare and fragile, and it has significant social and economic value (Yepes and Medina, 2005; Alexandrakis et al, 2015). It provides important ecosystem services, such as coastal buffering, biodiversity, recreational and cultural value (Semeoshenkova and Newton, 2015). Furthermore, it is extremely important for the tourism industry and, for this reason, its protection is vital for the economy. In this sense, many are the investments that coastal authorities provide to enhance the recreational quality of beaches and to prevent them from coastal problems.

As a natural process, or triggered or exacerbated by human actions, coastal erosion is one of the most common problems of sandy coasts. The Eurosion Project (2004) estimated that about 20.000 kilometres of the European coastlines are affected by serious coastal erosion. Regarding Italy, the project highlighted that the Italian coasts are affected by severe erosion, and that about 2.349 km of all Italian coastlines and 42% of beaches are eroding. Coastal erosion may be associated to coastal infrastructures damage and hazard, but the main negative impact is the loss of tourism and recreation by the loss of their spaces.

Coastal areas represent the transition zones between the continent and the sea, where the dynamics of these systems intersects and merges. The low-lying coastal areas are particularly sensitive to this dynamics, already threatened by the sea level rise. The sea (and its energy) operates fundamental actions on granulometric screening of the sediment and on the transport parallel and perpendicular to the coastline. In turn, the mobility and deposit of the sediment derive from the simple balance between the incoming and outgoing sediment, where the positive difference enriches bars and dunes, whereas the negative ones erodes them.

Among the coastal areas most studied for their sensitivity to the variations induced by natural factors and substantial anthropogenic modifications, we point out the Ionian side of Basilicata region (the south of Italy, Fig. 1).

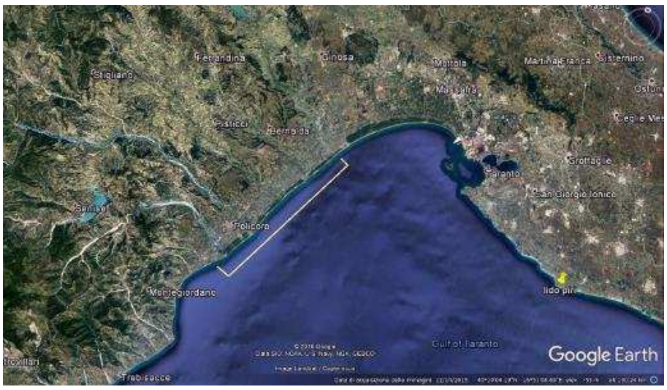

Fig. 1 - Ionian Basilicata coastline.

The coastline in question is about 35 km and it is characterized by a low-lying coast, fed by 5 rivers with prevalent torrential flow. Before about 1950, the Ionian Basilicata coastline was in clear extension, with evident cuspidate river mouths. From that date, a building era of linear infrastructures (such as primary roads) parallel to the coast and of dams for water storage (for drinking, industrial and irrigation uses) began.

To these huge changes in the river catchments, firstly the Ionian Basilicata coast responded by taking back its deposits (dismantling the dunes) and then it began an intense process of coastal erosion, particularly developed in some areas (Spilotro et Al, 2004). In 2006 and 2012, on such a scenario of severe sedimentary deficit, there were built two inland marinas near the river mouths of Agri and Basento rivers. Both entrances of tourist ports were protected by two breakwaters parallel to the coastline, which has not been insensitive to these new actions.

During last decades, some techniques with beach nourishments and the BMS (Beach Management System) have been experimented to reduce the impact of the coastal erosion. These techniques were effective, but they resulted unsustainable from economic and management point of views.

At the end of 2013, intense sea storms hit the coastline. Moreover, several meteorological events interested the river catchments which refer to the Ionian coast of Basilicata region. Among others, the results of these natural phenomena are visible at the mouth of rivers, in particular Agri and Basento rivers, that were already suffering because of the breakwaters of the tourist ports.

Finally, from 2015 onwards, a limited stretch of coastline (around 3 kilometres) has been protected by submerged breakwaters. The response of the coastline has been prompt, highlighting inhomogeneity and a modest positivity. Previous studies allowed us to define the amount of the lost sediment caused by the multiple rivers damming.

2 Methodological approaches to analyse coastal erosion

Studies on the dynamics of the Basilicata coast began more than 30 years ago. Among this period, the measurement techniques have been updated several times, passing through topographic maps and aerial photos digitalization and georeferentiation , LIDAR scanning and GPS tracking, up to the high resolution of satellite images. Depending on the time intervals analysed, the following analyses are based on all the cited methodologies (Dolan et Al., 1991; Thieler et Al., 2009; Aiello et Al., 2013 b). The sedimentary balance at the mouth of the rivers has been evaluated through sediments production and transport models (such as RUSLE and Gavrilovich), calibrated on the silting data available for some dams (Spilotro et Al., 2018).

3 Dams, barrages and sedimentary deficit

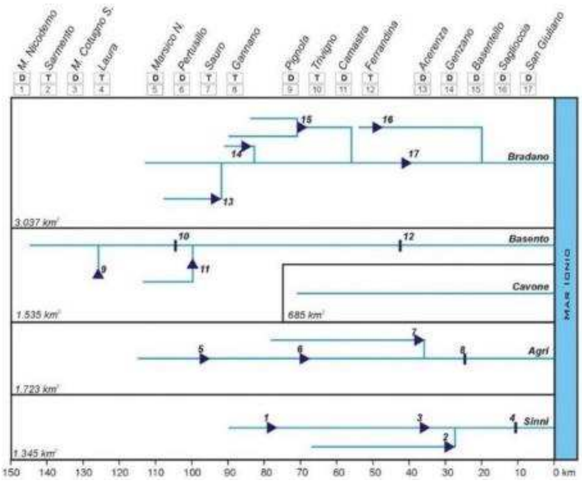

Fig. 2 - Layout of the five Basilicata rivers with dams (D) and barrages (T) along them (from Spilotro et al. 2004).

Deficit in sediment budget caused by dams and minor barrages along rivers is the basis of widespread delayed coastal erosion phenomena worldwide. Measurements of the Ionian littoral shoreline variations highlight a diffused and huge retreating phenomenon, starting in the second half of the 20th century, with increasing intensity over time until now. The delay first and the progressive increase of the phenomenon over time is mainly due to the sedimentary deficit and to the progressive consumption of the sands stored into the dunes and the longshore bars.

An evaluation of the sediment deficit at the Ionian river mouths of the Basilicata Region between 1977 and 2014 is available; the results come from the comparison of several methods for the assessment of the catchment basin erosion, validated on the basis of the available silting data for some basins.

The intercepted sediment in the river catchment areas operated by dams results 42%. According to the heuristic model of Gavrilovic, the year mean sediment yield is about 4.250.000 m3, whereas the amount of sediment yearly trapped by dams is 2.150.000 m3. Finally, the amount of sediment delivered at the mouth of the rivers at the present (after the river damming) is 1.540.000 m3/y. This means that all reservoirs intercept 45% of the sediments produced by natural erosion processes in the whole catchment area, but the real amount of sediment (that reaches the sea and feeds the beaches) is only 36% of the total amount of moved sediment: downstream of the dams, the driver of the residual sediments, the water, is reduced in quantity and in energy. The conclusion for the examined territory investigated is that, after the season of river damming, the mean yearly sediment budget has been reduced of 64%. In terms of coastline variation, measurements with appropriate techniques give us information of the rate of lost surface (Table 1) and of the velocity of the coastal retreat, which at the last measurement has the mean value of about 70.000 m2/year.

Table 1 – Eroded and increased coastal areas, and variation rate from 1870 to 2014.

Time interval	Eroded coast (m^2)	Increased coast (m^2)	Net difference (m^2)	Number of year	Erosion velocity (m^2/year)
1870-1954	-825.944	5.436.087	4.610.143	84	54.883
1954-1988	-1.009.570	965.859	-43.711	34	-1.286
1988-2000	-758.191	148.495	-609.696	12	-50.808
2000-2005	-314.932	327.523	12.591	5	2.518
2005-2104	-803.501	174.472	-629.029	9	-69.892

4 The construction of two inland tourist ports

In 2006 and 2012, two inland tourist ports protected by two breakwaters were built. Starting from then, breakwaters have modified the sediment distribution transported by marine currents, principally directed from SW to NE, accentuating deposition in the southernmost part and increasing erosion in the other part of the coast. The studies conducted after the construction of the tourist ports highlight this phenomenon. Figure 3 represents the 2013 coastline, obtained by a satellite image, on which overlaps the 2005 coastline (red line), which is antecedent the construction of both tourist ports, and the 2014 coastline obtained by GPS on-field land survey. In the right riverside of Agri river, the shore lost 175 meters of thickness.

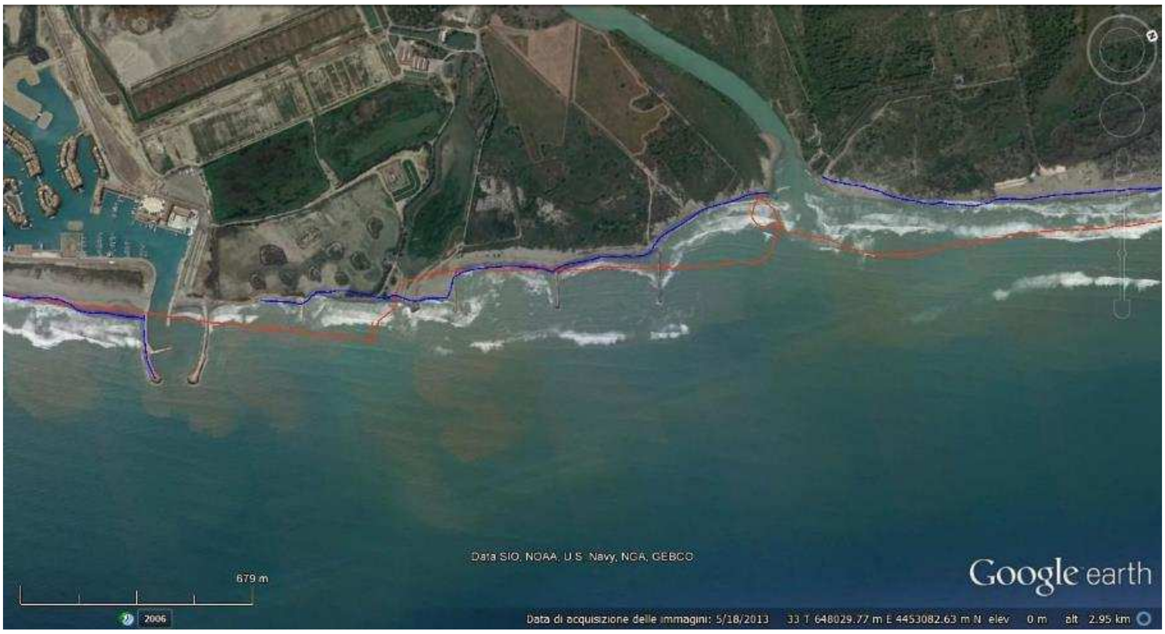

Fig. 3 - 2005 coastline (red line) and 2014 coastline (blue line) overlapped on 2013 Google Earth Satellite Image.

The sedimentation disturbance has interested other coastline areas, in particular those which are near the river months interested by the construction of the two inland tourist ports (Fig. 4).

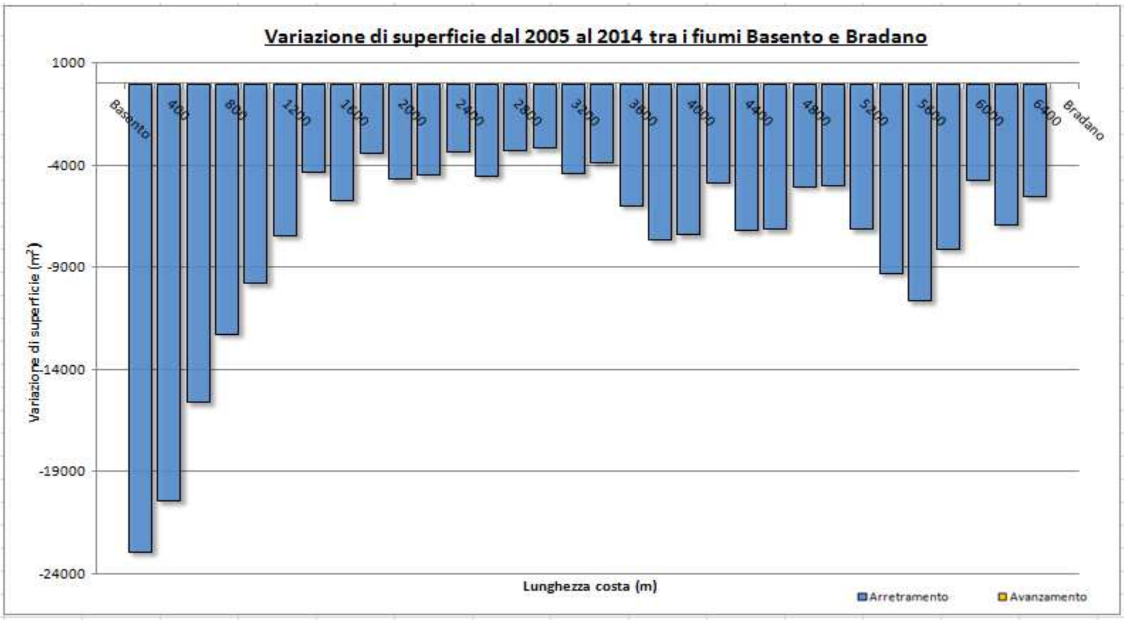

Fig. 4 - Erosion along the coast between the Basento and Bradano rivers, between 2005 and 2014.

5 Meteo-climatic events at the end of 2013

At the end of 2013, meteorological events interested the Bradano and Basento river catchments, with 260 mm of precipitation in two days Among others, and intense sea storms hit the coastline. These natural phenomena have caused the activation of large landslides and, despite an exceptional sediment transport, a further backward of coastline. The result is evident confronting the 2013 coastline and the 2014 coastline (detected by GPS on-field land survey) (Fig. 5).

Fig. 5 - Coastal erosion near the mouths of the Agri and Basento rivers following the storms of late 2013.

6 The construction of submerged breakwaters

The whole coastal area is vital for the local economy. As the matter of fact, there are a tourism growth from a local to an international scale and a high-quality (and large quantity) agriculture production. As seen above, coastal erosion of Ionian Basilicata coastline is not a natural process exacerbated by the sediment transport reduction due to the construction of dams and barrages for water storage (for drinking, industrial and irrigation uses). One of the main eroded coastline is the stretch between Basento and Bradano rivers (Fig. 6), where starting from 2014 submerged breakwaters were built for a 3 kilometres coastline stretch.

Fig. 6 - Submerged barrier to protect a stretch of Ionian Basilicata coast: comparison between 2015 2018 coastline.

Conscious that the time interval of analysis is still too short to assess the effects of these protection works, the comparison between 2015 and 2018 coastlines highlights a non-resolving effectiveness of the erosion problem.

7 Conclusion

The demand for drinking, irrigation and industrial water led in the years between 1950 and 1975 to the construction of a number of dams and barrages on 4 of the 5 rivers of the Ionian Basilicata coastline. These dams caused the crisis of the sediment budget, as expected but not considered in the associated environmental costs and remediations. The coast has been further unbalanced by the construction of breakwaters to protect the entrances of two tourist ports. The recent meteo-climatic events have not helped the protection works, that have been put in place to date. From this study, the language of the coastline emerges, which responds punctually, and almost always critically, to the activities that involve it.

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Limitations of using weighting-rating and quality index methods to assess seawater intrusion: the case study of Thermaikos Gulf (Greece)

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1. Introduction

Almost 50% of world's population lives near the coastline (Reed, 2010) and coastal aquifer systems represent the main source of water for their activities. Aquifer salinization and seawater intrusion (SWI) represent the main threats to coastal aquifer due to overexploitation of freshwater resources and variation in recharge (climate changes). This problem becomes more serious in arid and semi-arid regions where a groundwater management plan is mandatory for a suitable management of resources. In the last decades, many methodologies have been proposed for the assessment of SWI, from numerical models to overlay and quality indices. The GALDIT index (Chacabi and Lobo Ferreira, 2007) is one the most used and modified overlay index for the assessment of SWI (Bouderbala et al., 2016, Allouche et al., 2017, Kazakis et al., 2018). GALDIT clusters together physical and chemical parameters to assess SWI. On the other hand, GQI (Groundwater Quality Index) uses only groundwater chemistry in understanding the magnitude of SWI. Tomaszkiewicz et al. (2014) developed GQI_{SWI} (Groundwater Quality Index for seawater intrusion) that provides vulnerability maps, allowing also for the spatial distribution of SWI. The aim of this work is to apply both GALDIT and GQI_{SWI} in a coastal area of Greece to verify the differences and the suitability of these two methodologies.

2. Materials and methods

2.1 Study area

The study area is located in Northwest region of Chalkidiki, Greece, and occupies the coastal area of eastern Thermaikos Gulf, from Nea Kallikratia to Flogita (Figure 1). The site extends for 12 km starting from the coast to inland for a total area of 152 Km^2. The climate is typical Mediterranean semi-arid, characterized by dry summers and wet winters with heavy rains. From the lithological point of view, sedimentary formations occupy most of the study area with Neogene and Quaternary sediments represented by marl, red clay series and alluvial deposits (Figure 1).

Within the study area, 34 standard long screen boreholes were investigated for hydrogeological parameters and 27 groundwater samples were collected from domestic and agricultural wells to be analysed for anions and cations after purging at least 3 well volumes.

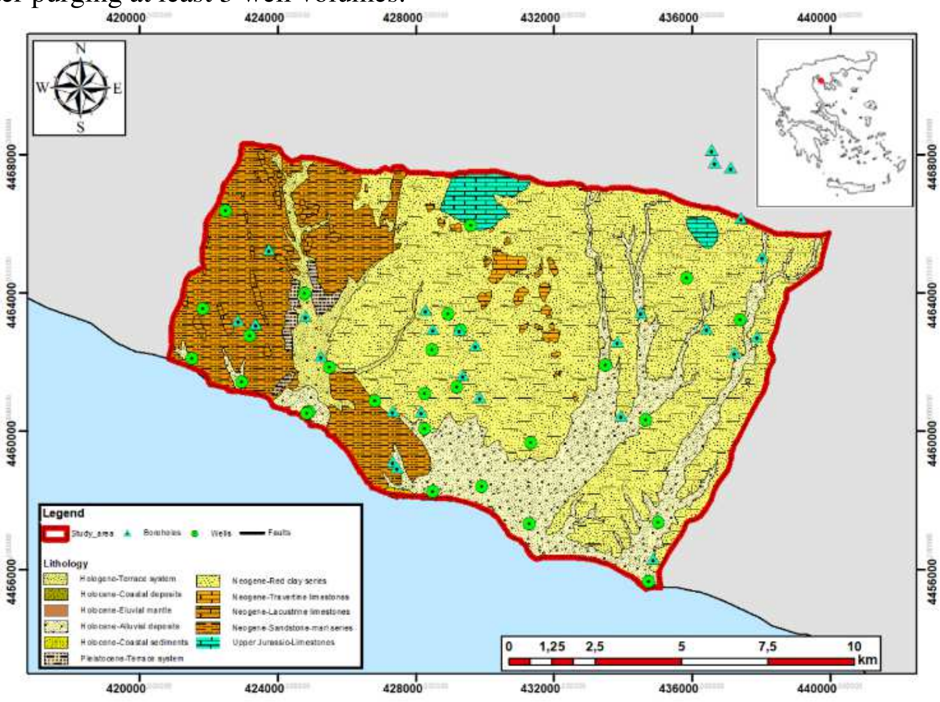

Figure 1. Lithological map of the investigated area with boreholes and wells location.

2.1 The GALDIT method

GALDIT considers six parameters: (G) groundwater occurrence, (A) aquifer hydraulic conductivity, (L) depth to groundwater level above the sea, (D) distance from the shore, (I) impact of existing status of seawater intrusion, and (T) thickness of the aquifer. Each parameter (R) has a relative rate varying from 2.5 to 10, where 10 is very high vulnerability, and weigh (W) varying from 1 to 4. The final SWI map is calculated following the formula:

$$\text{GALDIT Index} = \frac{\sum_{i=1}^{6}(W_i * R_i)}{\sum_{i=1}^{6} W_i}$$

2.2. The GQI_{SWI} method

The groundwater quality index for seawater intrusion (Tomaszkiewicz et al., 2014) is a mathematical combination between two different indices: i) $GQI_{PIPER\ (MIX)}$ that numerically accounts for the seawater/freshwater mixing in the Piper diagram and ii) GQI_{fsea} that is the percent fraction of seawater inside the sampled groundwater. These indices are calculated according to the three formulas reported below.

$$GQI_{PIPER\ (MIX)}\left(\frac{meq}{l}\right) = \left[\frac{Ca^{2+}+Mg^{2+}}{Total\ cations} + \frac{HCO_3^-}{Total\ anions}\right] X\ 50$$

$$GQI_{fSea} = \left[1 - \left(\frac{m_{Cl\ sample} - m_{Cl\ freshwater}}{m_{Cl\ seawater} - m_{Cl\ freshwater}}\right)\right] \text{X } 100$$

$$GQI_{SWI} = \frac{GQI_{PIPER\ (MIX)} + GQI_{fSea}}{2}$$

The m_{Cl} for sample, seawater and freshwater is expressed in meq/l. The values used to calculate the GQI_{fSea} index correspond to 570 meq/l and 0.3 meq/l for seawater and freshwater respectively. The GQI_{SWI} values vary between 0 and 100 where "0" represents seawater and "100" represents freshwater. GALDIT and GQI_{SWI} were compared versus groundwater Cl^- concentrations using the Pearson's r correlation coefficient, extracting the calculated values from the raster grids (20x20 m) of both methods at each well location via GIS (Geographic Information System) functions.

3. Results and discussion

3.1 GALDIT application

All GALDIT parameters were evaluated according to the methodology described above and reported in GIS environment. The aquifer occurs in both confined and unconfined conditions and the hydraulic conductivity ranges from 3.0 to 0.03 m/day for the sandstone and the clay series, respectively. 1) Piezometric heads show negative values from the coastline towards 3 km inland and represent the main driver for SWI. The distance from the shore was calculated using 4 buffer zones (500 m, 750 m, 1000 m, >1000 m) and the impact of the existing SWI was represented by the Revelle ratio (1941). Finally, the aquifer thickness shows high values in all the study area, from 20 m in the southern part to 70 m in the North. The final map (Figure 2a), calculated with Eq. 1, divides the study area in three classes of vulnerability: very high, moderate and low. More than 50% of the study area is characterized by a moderate vulnerability due to the unconfined condition of the aquifer and to the negative piezometric heads. Low vulnerability spreads in the eastern part of the site where positive values of groundwater level above the sea may be found. A small portion of very high vulnerability is located near the coastline.

2)

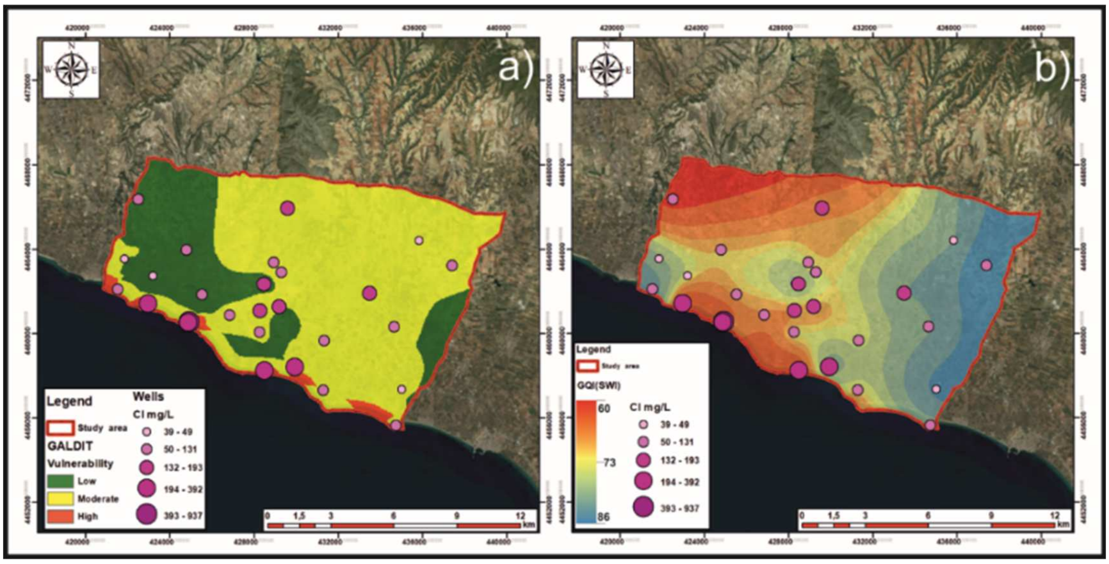

Figure 2. GALDIT vulnerability (a) and GQI_{SWI} (b) maps for the study area.

3.2 GQI_{SWI} application

All The GQI indices were calculated using major ionic concentrations for the 27-groundwater samples. The GQI_{fsea} shows a minimum of seawater contamination equal to 0.2% and a maximum of 4.7%. The $GQI_{PIPER(MIX)}$ classified the groundwater in 2 main Piper domains: Ca-Cl and mixed Ca-Mg-Cl. The final GQI_{SWI} index (Figure 2b), calculated with Eq. 2, ranges between 60 and 86 with all samples falling in the category of mixed waters. The spatial distribution of the index was obtained using kriging (Wang et al., 2001). The most saline waters are located in the central part of the region, especially along the coastline and in the sand deposits, while in the East part of the area groundwater becomes fresher, though affected by SWI near the coast.

3.3 Methodologies comparison versus Cl- concentrations and drawbacks

Despite both methodologies show a positive correlation (Pearson's r correlation) with Cl-, namely 0.23 and 0.40 at $p<0.05$ for GALDIT and GQISWI respectively; the correlation is too weak to be considered good. Moreover, previous studies confirm that SWI extent up to 1 km from the coastline (Gavriilidou et al., 2017), while GALDIT depicts small portions near the coast characterized by high vulnerability (Fig. 2a). The same apply to GQISWI, which suffers also from the influence of geothermal waters. The latter are present in the North-Western portion of the site, which can be confused with SWI phenomena. Least but not last, the utilization in both methods of Cl- coming from integrated depth samples makes impossible to distinguish between actual SWI and paleo-saline groundwater due to Quaternary eustatic level variations, leading to a misleading reconstruction of SWI (Colombani et al., 2016).

Conclusions

The study investigated two well-known different methodologies for assessing SWI: i) the overlay index method GALDIT and ii) the quality index GQISWI. The first is a weighting and rating method using hydrogeological and chemical parameters, the second is a mathematical expression using ionic concentrations of groundwater. The methods failed to correctly describe the seawater intrusion phenomenon due to other salinization processes such as geothermal fluids influence and probably upconing of paleo-saline groundwater. Thus, the results highlight the limitations of both the applied methodologies to estimate the SWI processes in areas characterized by complex hydrogeological and geochemical features. Here, the use of multi-level sampling techniques could improve the conceptual model and consequently the water resources management plan.

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Potential sediment resources for coastal defence strategies

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Introduction

Coastal erosion is a serious problem for people in Europe and all over the world. Most of Europe's coastline is eroding and erosion threatens some of the values and functions of the coast. It was estimated that about 15,100 km of European coastline is retreating (out of a total of 101,000 km at the scale they used) and that about 15 km^2 of land is lost each year (European Commission, 2004; Sutherland, 2010).

Coastal erosion is usually the result of a combination of factors - both natural and human induced - that operate at different scales. The main important natural factors are: winds and storms, near shore currents, relative sea level rise and slope processes. Human induced factors of coastal erosion include: coastal engineering, land claim, river basis regulation works (especially construction of dams), dredging, vegetation clearing, gas mining and water extraction (European Commission, 2004). Moreover, phenomena related to the beach retreats can produce not negligible damage on coastal environments in terms of loss of natural landscapes, with effects on peculiar and sensitive habitats and species.

Historically many hard structures were realized to stop or reduce local erosion. The adoption of these techniques has caused a complete artificialization of forcing factors and boundary conditions, further aggravating the problem. Analysis on these developments has led to the current tendency of using 'soft defence techniques', building with natural processes and relying on natural elements, as a more appropriate approach to be used in Integrated Coastal Zone Management (Capobianco & Stive, 2000).

Amongst these soft techniques, beach nourishment has proven to be a successful coastal protection method and it is considered to be one of the main tools for coastal management: it is the practice of adding large quantities of sand or sediment to beaches to combat erosion and increase beach width (Nonnis *et al.*, 2015). In fact, since the economic value of beaches, particularly those devoted to public recreation, is highly dependent on the aesthetic quality of the beach itself, beach nourishment are generally believed to be the most effective, soft-armoring method for mitigating the impact of erosion and, consequently, for helping to maintain and enhance the recreational value of beaches (Fletemeyer *et al.*, 2108). Sediments used for beach nourishment can have a different origin, ordinarily comes from terrestrial quarries and marine environment such as river beds, canals, ports and offshore deposits.

In the Mediterranean Sea, characterized by a reduced continental shelf (low availability of offshore sediment) associated with a very high coastal anthropization, the identification of all the possible sediment resources to be used for coastal adaptation strategies (on a medium and long term period) has become a key theme of national interest. It has been estimated that in Italy, to maintain the current shorelines till to 2080 in response to the sea level rise (not considering local effects such as subsidence and coastal erosion), it would need more than 2.5 Mm^3/year of sediments to be used for nourishment (MATTM-Regioni, 2018).

It is therefore evident the strategic importance of knowing the different sediment resources to be used for coastal defence strategies in the frame of the sustainable development and integrated coastal zone management. In fact, this issue has also been addressed within the "National Guidelines for the defense of the coast from erosion and the effects of climate change" (MATTM-Regioni, 2018). In this paper the potential types of sediment resources are considered, analyzing the main environmental and regulative aspects related to their exploitation.

Potential sediment resources

In general, sediments that can be used for coastal defence strategies refer to 4 main groups defined according their "origin": offshore deposits or relict sand deposits, coastal deposits, river deposits (artificial reservoirs) and excavated soil and rock. The first group includes offshore deposits or relict sand deposits. Relict sands are non-diagenized sedimentary deposits situated at variable depths along the continental shelf. These deposits may outcrop from the bottom or be covered by a pelitic layer of recent deposition. Relict sands generally contain large amounts of sediments that are similar, in terms of sedimentology, to the recent beaches. Due to the position and depth at which relict sands are normally found, their removal does not interfere with coastal dynamics (Nicoletti *et al.*, 2018).

The second group includes very different sediments characterized by the same depositional environment: submerged barrier bars at harbor mouth, foreshore bars, submerged bars at river mouth, lagoons and inlets, harbour sediments etc. This is an extremely heterogeneous group of sediments that can be often interested by significant contamination phenomena.

To the third group belong sediments accumulated inside artificial reservoirs: the river dikes retain and accumulate waters for different purposes (energy production, irrigation etc.) also blocking the sediment transport and determining their accumulation inside the reservoir. Depending on the burial rate of each basin, it is always necessary to intervene for the removal of sediments accumulated at the bottom, adopting effective and sustainable procedures, minimizing costs and impacts on the environment. According to the Legislative Decree 152/2006 these operations must be foreseen and described in the Regional Management Plans.
Finally, the last group includes the excavated soil and rock classified as "by-products" of specific works and/or activities (coming from small, large and large shipyards not subject to EIA or IPPC, including those intended for the construction or maintenance of infrastructures) as defined in Regulation DPR 120/2017 on "simplified land and rock routing". Only few Italian regions (as Liguria, Veneto and Emilia Romagna) allow the use of these materials for nourishment interventions.
In this paper, sediments coming from quarries are not examined because of their high costs (above all for large amounts of sediments). In fact, in addition to the costs for their handling, must also be also considered those related to their purchase.

Environmental aspects
It is generally known that the main effects induced by the sediment handling depend on quality, type, volumes of sediments to be handled, on the environmental characteristics of the borrow area (OSPAR, 2014; McCook *et al.*, 2015), as well as on the techniques used.
The sediment handling in aquatic environments can involve effects on the water column, on the sea bottom and biota. In order to assess the potential environmental impacts must be analyzed the following main aspects:

- the presence of contaminants in the sediment that can be released in the water column during the dredging process;
- the fine fraction in the sediment that can induce a significant increase in the suspended sediment concentration with a consequent increase in turbidity;
- the presence of protected habitats types (*sensu* EU Habitats Directive) and sensitive flora and fauna species. Main impacts can be related to defaunation or burial phenomena since some species can suffer the changes in turbidity especially in some phases of their life cycle. Particular attention must be paid also in presence of species of commercial interest (i.e. fishing activities) that can induce socio-economic repercussions at local scale.
- the morphological and sedimentological characteristic of the bottom; for example furrows and pits caused by relict sand dredgings have been reported to remain, as recognizable seabed features, for several years and up to decades (Hitchcock & Bell, 2004; Garel *et al.*, 2009; Nicoletti *et al.*, 2018). Moreover in coastal areas effects can also be expected on coastal dynamics, e.g. increasing erosion phenomena *in loco* e and in adjacent areas (PIANC, 2010; CEDA, 2015).

As regards the excavated soils and rocks it is important to underline that, being these materials "by-products" of productive activities, only the sediment quality has to be assessed.

Regulative aspects: sediment quality
It is important to underline that, in Italy, only unpolluted sediments with a suitable grain size may be used for beach nourishment purposes; in fact it is well documented that chemicals in sediments are responsible for toxicity and adverse ecological effects (Onorati *et al.*, 2015).
Concerning the chemical reference values to be used for the sediment quality assessment, the situation is quite complex and must be analyzed, case by case, according to the different type of resources, in accordance with the provisions of Legislative Decree 152/2006:
• offshore deposits: there are no specific regulations, but in Italy it is possible to refer to technical manuals, which report the analysis to be carried out for the sediment characterization (Nicoletti *et al.*, 2018).
• coastal deposits: the quality assessment must be carried out in accordance with the provisions of Decree 173/2016, based on an integrated chemical-ecotoxicological approach aimed to define suitable management options of dredged sediments.
• artificial reservoirs: specific regulations are not available. The Legislative Decree 152/06 does not mention lacustrine sediments; some proposals for the definition of the quality standards and for the characterization are reported in the literature (ISPRA, 2011).
• excavated soil and rock: specific indications have been defined in some Regions. For example, the Liguria Region has identified legal standards for the investigations to be carried out on these materials, focused on the chemical and petrographic characteristics analysis (in order to exclude the presence of asbestos).

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Soft and hard coastal transformation: effects on benthic marine habitats around the coasts of the Ischia island

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Many marine macrophyte, such as the seagrass *Posidonia oceanica* (L)Delile and the macroalgae belonging to the genus *Cystoseira*, are considered engineering species and play a relevant structural and functional role in marine ecosystems. They are experiencing a huge decline in many areas of the Mediterranean basin, mainly along the most urbanized regions. The man made coastal transformation can be considered one of the causes of natural habitats and biodiversity loss. Here we report two key studies performed along the coasts of the island of Ischia (Gulf of Naples, Italy) on the effects of soft and hard transformation on benthic marine habitats. The sand extraction for the nourishment of the front Maronti beach on the south side of the island caused the loss of more than half of a deep Posidonia meadow, without any compensation. After years, the fate of this prairie seems foretold. On the opposite side of the island, the most impacted by proliferation of harbours, marinas and artificial barriers, the complete loss of shallow *Cystoseira* species has been derived by a comparison of historical and current records of these algae. A stronger collaboration between engineers, managers and ecologists for a better planning and management of coastal zones, in order to mitigate the impacts of continuous coastal landscape transformations and to preserve biodiversity, has to be pursued.

Keywords

Habitat loss, Coastal transformation, Beach nourishment, *Posidonia oceanica*, Regression

1 Introduction

Coastal areas represent only 10% of the earth's land surface yet more than 60% of the human population lives in these zones; forecasts for the next decades foresee a further increase, as urbanization is driving a movement in population towards the coast.

A wide range of services are provided by marine and coastal ecosystems, the continuity of which has to be managed and guaranteed against the human settlement, the increasing sea over-exploitation and the coastal transformation. However, the proliferation of harbours, marinas, and artificial barriers to protect beaches from erosion are destructing natural habitats introducing new ones that can contribute to fragment and segregate marine benthic populations, altering their natural connectivity, and at last, causing a loss of biodiversity (Pimm and Raven, 2000). In addition, the social concern about sandy beach erosion has enhanced actions to guarantee the same uses and benefits of the coast through out artificial beach nourishment. This practice, altering the local sediment dynamics, can have a strong impact on both the area affected by the excavation for sand extraction as well as on the local subtidal environments of the zone facing the nourished beach. Here we report the effects on benthic biota of two coastal actions performed along sandy and rocky coasts of the island of Ischia.

In the Southern side of the island of Ischia, a large patchy meadow of *P. oceanica* was present in the most sheltered part of the Maronti Bay, at about 600m far from the coast line, extending from 16 to 25m depth, and building in some areas a matte up to 2m high. In 2002 sand extraction activities, related to a beach nourishment action, were carried out for less than 24hours but with dramatic effects. About 4 hectares of meadow between 18 and 25m were destructed. Two years later, the residual meadow was limited to 2 hectares only, in the westernmost and shallower portion of the bed, with a highly patchy distribution, between 16 and 20m depth. The shoot density measured in 2004 and 2005 gave back lower values but yet in the Normal Class, according to Buia et al. (2004).

A drastic decline of *Cystoseira* spp, a group of dominant, habitat-forming species, has been recorded on rocky coasts in the last decades in the Mediterranean basin (Thibaut.. et al., 2014). Their decline is much more relevant as some taxa are considered biological elements of water quality (Ballesteros et al., 2007). A long-term analysis has recently been performed comparing their historical-present occurrence (1878-2013) in the Gulf of Naples and a drastic decrease has been highlighted also for the coasts of the Ischia island (Buia et al., 2013). In the same time range, the coast line of this phlegrean island has been largely transformed (Zocco, 2003).

2 Materials and Methods

In order to monitor the ecological status of Posidonia meadow in the Maronti Bay after the beach nourishment, a survey has been conducted in the summer 2016. Some parameters have been obtained *in situ* directly (lower limit depth and tipology, cover, shoot density and leaf surface) in order to calculate the BiPo Index (Lopez y Rojo et al., 2010). In addition, two other synthetic environmental indices were applied: the Conservation Index (Moreno et al., 2001) and the Substitution Index (Montefalcone et al., 2006). The former is related to the proportion of dead matte; the latter is measuring the amount of replacement of *P. oceanica* by other macrophytes.

As regards the decline of the *Cystoseira* group on the shallowest rocky substrates, the percentage of coastal landscape transformation has been quantified for the Ischia Island and the introduction of different hard structures has been quantified by using ortho-photos selected from Google Earth™. These structures have been classified according to their source: natural rocks and human-made buildings. In the first category natural blocks of different geological origin with various forms and slopes have been included. A second category has been created for human-made constructions, usually done of concrete. Surfaces covered by each hard artificial substrate were quantified and georeferenced in a GIS database. The total surface of the structures has been computed according to their distribution around the island and the current presence of Fucales has been extensively mapped within the shallowest rocky fringe.

3 Results

The analysis of the nature of the Ischitan coastline pointed out a development of artificial constructions for 9,605, representing about 25% of the total coastal length. (Table 1).

The loss of historical records of fucoids in the different sectors in which the area has been divided seems to correspond to the intensity of the development of artificial infrastructures (Tab. 1). In particular, on the north side where the man made alteration of the coast is highest, *Cystoseira* species are totally lost.

Table 1: Sectors of the island of Ischia. (SCL=sector coastal length; N-TCSL=non-transformed coastal sector length; TSCL= transformed sector coastal length; %TL= percentage of TSCL for each sector).

	Geographical sectors	**SCL**	**N-TCSL**	**TSCL**	**% TL**
Ischia Island	North	10,570	5,110	5,460	52
	East	6,895	5,405	1,490	22
	South	13,872	13,192	680	5
	West	7,160	5,085	2,075	29
	Total length (m)	**38,497**			**25**

The dominant artificial structures around the coasts of Ischia island are breakwaters (about 185,000 m^2) and 49% of them are emergent blocks, with various orientations and shore connections, mainly located on the northern side of the island, in front of sandy beaches. They are also deployed onto the original rocky substrate, with no respect for the geological nature of the local reefs. In general, no fucoid records were found on artificial structures, as they generally provide vertical substrates. Very few spots of fucoids have been found only on more than 30-years-old infrastructures (both natural and man-made) but only where the slope is very gentle and the artificial structures are close to the natural algal population.

Fourteen years later the beach nourishment, the ecological status of the left prairie in the Maronti Bay is the worst, *sensu* WFD (Table 2).

Table 2: Conservation Index and Status, Sostitution Index, Ecological Quality Ratio and Ecological Status for the Maronti meadow 14 years later the beach nourishment.

Meadow	CI	Conservation status	SI
MARONTI	0.1	**BAD**	0
	EQR	**Ecological status**	
	0.252	**POOR**	

4 Discussion and Conclusions

The extent of the problem of beach erosion is alarming, especially around the Ischia island. Comparing the extension of its beaches between the sixties and 1999, a loss of 65% of sandy shore is evident (Zucco, 2003). Hard artificial structures have become ubiquitous features of coastal landscapes However, the attention on the impacts that artificial structures may have on the marine native ecosystems is very poor (Chapman & Bulleri, 2003) and it seems that the nature of the rocks that have to be introduced in the sea has not taken into account. The natural settlement on artificial substrates can be possible but it seems mainly related to the distance of fertile populations on nearby natural substrates. The beach replenishment, completed with sand coming from another area, failed to mitigate the coastal erosion of the Maronti beach and submerged breakwaters were positioned. Finally, the lost of the Posidonia meadow and of its rich complex system was vaine and not compensated.

A stronger collaboration between engineers, managers and ecologists for a better planning and management of coastal zones, in order to mitigate the impacts of continuous coastal landscape transformations and to preserve biodiversity has to be pursued.

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Low coast development and environmental protection in Italy: from history to the future

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Objective

Analysis of the continuous competition between human and economic development of low coasts and the possibilities of environmental protection in Italy. Economic reasons for damage to the environment even in pre-tourist times. Coastal railway lines and comparison with the major roads. Competition between longitudinal roads and crossroads, combed development. Short-term optimization and tourism resources. The landscape-cultural mosaic: the absent network and its recovery. Who will win?

Lagoons and tombolos

We will mostly take care of the evolution of the lagoon and marsh coasts of the Italian peninsula, considering other cases only for comparison.
The significant new entries of the last seventy years are not many. Cases of design from scratch are rare. Generally there is only the enlargement and the superfetation of the original situation, even if not structured. The sandy beaches see an important recovery perhaps more in numbers than in prestige: the most famous on the Tyrrhenian are Forte dei Marmi, Viareggio, Fregene, on the Ionian Gallipoli and Otranto are fashionable, but then to find internationally known places the tourist must reach Riccione, Rimini and further Iesolo and Lignano. The Lido of Venice has completely different historical and logistical characteristics, so it can not be belong to this list, but it is anyhow one of the first beaches with organized bathing facilities, just like Grado. On the whole, the cases of great progress from scratch on sandy beaches have occurred in Fregene, in Iesolo and in Lignano, they too originally tombolos surrounded by marshes and lagoons.
The conservation of nature in the lagoons of the Po Valley and Veneto will favor a strong recovery of the low and marshy areas from Ravenna to Monfalcone. The places in competition are perhaps the Park of San Rossore, the mouth of the Ombrone, Orbetello and the lake of Burano, Sabaudia and its coastal lakes, the salt pans of Margherita di Savoia, the lakes of Lesina and Varano. The Po Valley-Veneto complex is now protected by a succession of natural reserves, starting from Ravenna with the parks of San Vitale passing through the Valli di Comacchio, and reaching the Po Delta, a vast jagged and articulated area. The Venice lagoon is a resource difficult to repeat, despite the coexistence with a large city and a massive industrial area. The lagoon of Caorle retains significant traces and one of the few stretches of coastal cordon between Iesolo and Grado exempt from tourist settlements (Brussa). The lagoons end with the vast lagoon of Grado and Marano.
The great obstacle to the conservation of the original environment was born from the reclamation policy, with the regulation of the waters and the elimination of the marshy areas, which indeed posed considerable health problems with the spreading presence of malaria. In addition to the Po Valley-Veneto area there was the whole area of the Maremma, the adjoining Pontine marshes and the Ionian area of Basilicata. One of the last reclamations was the elimination of the western part of the Valli di Comacchio (Valle di Mezzano).

Reachability and connection

In the Po Valley and Veneto area the railways have always remained far from the marshy coast, between 10 and 20 kilometers (40 near the Po), and the only transversal branch that reached the lagoon until the Forties consisted of the trunk from Cervignano to the Pontile (wharf) for Grado. It played an important role in connecting with the rich hinterland of the countries of the former Austro-Hungarian Empire, in particular with the Vienna area. In 1929, for example, starting from Vienna at 7.35 am it was possible to reach Grado at 11.00 pm. Tradition has allowed this historic beach to survive the tumultuous pressure of the new beaches of Bibione and Lignano. Today the railroad has been recovered as a cycle path and is part of the route that from Austria reaches the Adritiac at Grado and surroundings along the old Pontebbana railway.
To the south of Ravenna, on the other hand, the railway, even if secondary, closely follows the coast, up to Rimini, where it connects with Bologna-Bari. In particular, it encouraged the development of satellite centers around Rimini, starting from Cervia. In the Marche and Abruzzo it follows the coast too closely, running in some sections even on the beach.
The Ionian coastal railway joins Taranto with Reggio di Calabria. The trunk from the Lido of Metaponto up to Reggio di Calabria was for some years at the end of the nineteenth century part of the only railway that

connected Naples with Calabria. Until the end of the 1930s it remained the only coastal connection on the Ionian side, and was later joined by the 206 road, which today is one of the most dangerous roads in Italy.
Along the Tyrrhenian sea the mountainous areas have served as a track for the strenuous railway of the Ligurian coast and further south for the railway to Calabria from Cilento. In these areas the railway for a long time constituted a link that flanked the slow cabotage connections. The Maremma plain was also followed along the sea, much closer than in the case of the Po Valley-Veneto, but not close to the beaches as on the Adriatic, also due to the lack of towns of reference. The distances between one station and another remained very high, as indeed along the lower Adriatic and the Ionian coast. The last two trunks of the list lie along the upper Adriatic and the railway is so far from the coast that the intermediate distances are comparable with those of the traditional line in the interior (the last item).

	Stations	Km	Av.Interval
Grosseto-Civitavecchia	7	107	15.3
Cecina-Grosseto	10	96	9.6
Pescara-Foggia	16	177	11.1
Metaponto-Taranto	4	43	10.7
San Donà – Cervignano	9	70	7.8
Venezia- Udine	21	136	6.5

Compare with the high density of stations along the two Ligurian coasts

La Spezia- Genova	30	97	3.2
Genova- Ventimiglia	32	154	4.8

The railways were born for global reasons of national communication, the motorways followed them except from Cecina to Civitavecchia and from Taranto to Sibari, where there are highways, and in the Eboli-Sant'Eufemia stretch where the old mountain road was followed. Coastal roads generally meet tourist needs. They had wide-ranging developments until the 1960s, but then the phenomenon found an ecological restraint for which neither the Cinque Terre coastal road was made, nor the road that should have crossed the Zingaro Nature Reserve between Castellammare del Golfo and San Vito lo Capo.
Coastal developments in sandy areas have occurred mainly because of the random expansion of pre-existing structures. A more organized case is that of Versilia, where the seafront from Marina di Massa to Viareggio was completed, highlighting in particular the role of Forte dei Marmi. A case linked to land reclamation is the coast at Sabaudia, where anyhow no harmful tourist sprawl has been realized. In the upper Adriatic the few coastal roads are connected to the various existing bathing areas, and generally do not form continuous structures leaving a combed road structure. The translagunar bridges of the 1930s (Marghera-Venezia and Belvedere-Grado) due to their transversal nature do not constitute a source of urban sprawl, and vice versa make the lagoon landscape more usable even for the mainland traveler. The Romea road instead in the stretch from Comacchio to Ravenna badly shares long-distance traffic with local tourist traffic.

Evolution Dynamics
The primary factor is imitation. The expansion of objectives is sometimes caused by the vertical completion of services that do not have sufficient demand for a single location or hotel. It is also implemented with the horizontal integration of nearby resorts that offer different resources (artistic, sports, entertainment, food and wine, events). Important for the marsh and lagoon areas is organized navigation between the islands, with the possibility of naturalistic excursions and relaxing.
Economic sustainability needs to achieve appreciable levels of system integration in the framework of the landscape-cultural mosaic. This is necessary both towards the catchment area and the overall on-site supply, which must be varied and attractive. The use of the coastal resource sees the competition of hotels and tourist villages with the holiday houses that today appear as a waste of resources. Meaningful parameters are the percentage of holiday houses and the number of beds in hotels; less precise are the positive or negative evaluation of tourist resonance. The following data of the upper Adriatic point out the potential evolution of the Lignano- Bibione complex, which could increase its integration by overcoming the Tagliamento river barrier

	Holiday	Apartments Total	Perc..	Hotel beds	Ratio between beds and holiday Apartm.
Iesolo	13883	20819	0.67	31233	2.25
Caorle	11721	15633	0.62	11506	0.98
Bibione	21311	24881	0.86	9681	0.45
Lignano	22622	25097	0.90	13270	0.59
Grado	7011	10498	0.67	4552	0.65

Local solutions generally carry less persistent damage, but they can favor a disordered and non-homogeneous development, while integration can create problems even at long-range, affecting the road system and its traffic.
Future development requires the intensification of tourism with low environmental impact, especially in means of transport. It is also necessary to have a good integration with the cultural and food and wine resources of the hinterland, whose accessibility must be increased, or restored with appropriate information campaigns.
The development models predict that even a location that starts at low levels can override known locations that do not bother to update their offer. This agrees with Bak-Sneppen's evolutionary theory, especially when applied to areas of limited internal contact. A typical case is the tourism development of Trieste compared with the stationarity of Venice. Venice is limited by the low commitment of revaluation of the natural resources of the lagoon, which would greatly expand the usable area, allowing a greater differentiation of the tourist demand. In Trieste, however, the negligence of the management of the Miramare Castle should be reproached, and above all the too frequent suspension of the Opicina streetcar which, given its power of panoramic display, could favorably compete with the famous images of the San Francisco streetcars.
The evolutionary mechanism of Bak-Sneppen is the following: if a location in its area is particularly weak, it is better to recycle it in some form. It is not said that there is success, but often, by chance, there is an improvement, which can also be considerable. However, the effect on nearby locations is important, both geographically and in a functional sense. They too, willy-nilly, are forced to some form of adjustment. It is not said that the effect is of improvement, there may also be a worsening due to uncritical imitation, or unsuccessful experimentation of new paths of development. An example is constituted by Grado, where the attempt to imitate the tourist development of Lignano has led to a flattening of the new structures of Grado Pineta, which in the last twenty years has shown all its limits.
In the case of the maintenance of the natural environment we have already commented on the effects of the remediation. The clamorous cases of cover-up and erosion that hit both Tyrrhenian and Adriatic beaches, sometimes also due to improper dams, must be recorded. The ingressions and floods that have deeply affected the Po Valley-Venetian plain are, on the contrary, scattered in time between the end of the Roman Empire and recent times. The containment actions are necessary and expensive but, moreover, are always called into question since too many requirements should be achieved and politically it is almost impossible to balance them in the long period.

Keywords: low coasts in Italy, lagoons and marshes, remediation, coastal railways, development of sea resorts

The beach is moving: a resilient approach for defending a fragile system

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Coastal erosion is related to the natural processes of marine dynamics, but it is intensified more directly by indiscriminate use of the coastline and the beach environment.
Beach erosion is a major problem along most of the world's sandy shores (Jacobson, 1989; Griffin, 1992) and the retreat of shorelines is most acutely perceived along developed beachfronts where coastal infrastructure is threatened by storm surge flooding. Public perception of the beach erosion problem is thus largely oriented to developed shores where the public resides or spends its leisure time (Finkl et al., 1997). Currently, about 40% of the of the world's population lives within 100 kilometres of the coast, (Masselink and Hughes, 2003; Losada et al., 2011); around just the Mediterranean coastline there are about 450 million people (Coccossis e Henocque, 2001). Furthermore, the Mediterranean is one of the world's most important tourist regions, hosting about 30% of international tourism (with over 100 million tourists per year) and characterized by significant seasonal population pressure.
This strong anthropic pressure along the coastal area, combined with potential threats due to climate-related changes which, as underlined by the most recent IPCC report, during the 21st century will include an acceleration in Sea Level Rise (IPCC, 2013). It has been assessed that the Mediterranean basin will be one of the most strongly impacted regions (Khouakhi et al., 2013); its sea level has risen on average between 1 and 1.5 mm per year since 1943, and now appears to be accelerating, with an increase of 20 cm already in some areas since the start of the century (Vargas-Yáñez, et al., 2010).
The first signs of coastal erosion in Italy were reported right at the beginning of the 1970s, as a consequence of the earlier economic boom which started during the 1960s, when small fishing villages gradually extended along the coast, thus becoming pleasant, though crowded, beach towns. Later, linking infrastructures such as streets, seafronts and port facilities followed.
The urbanisation of the shoreline, with the disappearance of dunes as a consequence of the building of roads, promenades, and other urbanisation processes (Burak, et al., 2004; Roig-Munar et al., 2005), marked the start of the first erosion processes of beaches that had effectively been stable until that time.
Indeed, we officially talk about a problem of coastal erosion, but it would be more correct to speak "of coastal occupation", because while on the one hand we register a retreat of the coastline, we must not forget that before this process the whole coastal area was occupied by anthropic structures.
In the 1980s and 1990s the problem was tackled simply through the use of extreme "hot spot" urgency measures, hard engineering methods (seawalls, breakwaters, groynes); these measures protected the land behind, but moved the erosive process down-drift. In this way, chain construction triggered a rigid response to the hardening of the shoreline.
Because of this, Italy, for the period 1998-2015, is the country with the highest expenditure on coastal protection activities in financial terms (85% of the total) when compared with other countries in the top five in Europe for similar expenditure, and the ratio shows how hot spot interventions are dominant when compared with "normal" planned expenditure (Fig. 1).
An example of this "hot spot" intervention, partly because of the good pictures available, and partly because it is replicable in most of the coastal "villages" along the Italian coast line, is Sant'Alessio Siculo, along the Ionian coast of Sicily.
In 1935 only, a wide beach existed; in 1970 there were a few houses in the middle of a coastal wood and only one large building (the first hotel) with a large beach in front; in 1980 everything changed: the hotel was incorporated into a linear urbanisation and a big, high promenade, with small squares that stretched out towards the sea, marked the border between sea and land (Fig. 2).
In just a few years, the remaining beach underwent erosion and a seawall at the base of the promenade was destroyed several times.

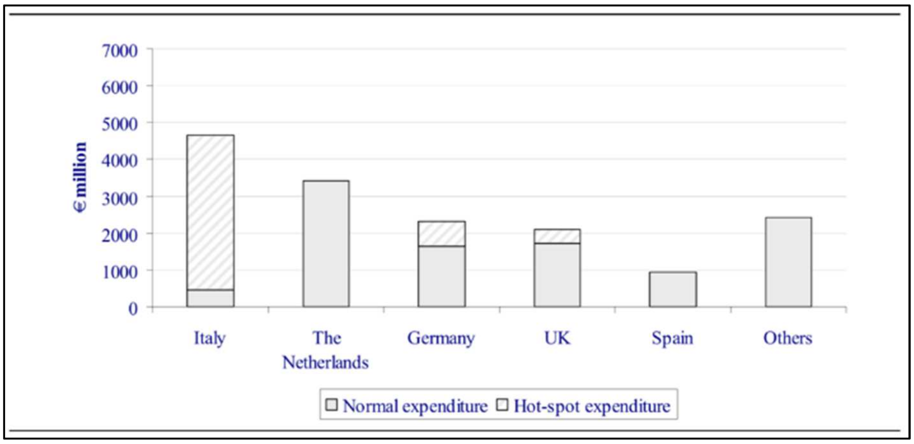

Fig. 1. Top 5 countries in terms of coastal protection and climate adaptation expenditure (Source: Policy Research Corporation)

In 2002, the municipality, with both EU and National Civil Protection funds, started a combined project of coastal defence, following the conventional system, which was still dominant at the time.
A very strong seawall and a submerged parallel barrier (reef barrier-like), with a nourishment of a few hundred thousand cubic metres, were constructed.

Fig. 2. Coastal evolution along the coast of Sant'Alessio Siculo, along the Ionian coast of Sicily.

The result was that, at the first small storm, the barrier was not strong enough to withstand the local wave climate, the seawall collapsed and the insufficient nourishment disappeared, leaving a post-earthquake scenario along the beach (Fig. 3).

Fig. 3 - Sant'Alessio Siculo, during and after the storm.

This behaviour is common for most of the beaches occupied by urbanisation and protected by rigid systems or with nourishment constructed with too little material.
Most of the Italian coastline is de facto occupied. It is also difficult to apply the European Directive (Bolkstein) on the management of coastal public soil, because of the opposition from coastal stakeholders, to the point that the Government has established an extension of current use for the next fifteen years; at this point, it appears almost impossible to propose the de-localisation of coastal urbanisation (including that which is illegal) or move promenades or coastal roads landward. It is not imaginable in our management scenario that there could be the possibility of adopting laws which re-consider the level of coastal urbanisation, such as in many European countries (Loy da Costa in Spain, the activity of the Conservatoire du Littoral in France or the de-localization of single houses in Holland or in Denmark).
The coastal system, because of its artificial stiffening, shows its own fragility, with the consequent exacerbation of the erosive process. In fact, rigid protection has given rise to the increase both in expenditure and in the threatened coastal area.
The alternative should be oriented towards a more natural way of counteracting coastal erosion, with the fragility of rigid occupation being replaced by the resilient action of a natural coastal border.
The beach is the first element which dissipates wave energy; it physiologically changes its morphology because of the season, shortening in winter and widening in summer, and it returns to its original shape again even after the most violent storms.
Creating new beaches, with nourishment techniques, able to react in a resilient way to weathering, means creating an artificial system, with natural characteristics (depth, grain size sediments and volume of emerged and submerged beach up until the closure depth), able to protect itself and the landward coastal area and able also to create the geomorphological environment for dune rebuilding (dunes being the indicator light of the naturalness of the system).
Beach nourishment has been used as a shoreline management tool at least since the 1920s (Hall, 1952), but since the 1970s it has gained in worldwide popularity and is now increasingly seen as an appropriate management solution in areas which are experiencing beach erosion (Blott and Pye, 2004).
Until just a few years ago in Italy, it was difficult to realize these interventions, because it was not easy to find quarries able to provide the environment-sustainable quantities of material needed.
Recent studies on relict sand deposits to be used for beach nourishment date back to the 1980s and 1990s (Nicoletti et al., 2006, Paganelli et al.2013); in the last decade several submerged deposits have been identified in the Northern Adriatic, off the coast of Lazio and the Gulfs of Palermo and Termini Imerese, around the 100 m bathymetry. At this depth, submerged paleo-beaches are present, left there during the Last Glacial Maximum, about 18.000 b.p, when water was trapped in the ice in northern–central Europe and the Mediterranean coastal border corresponded with the present-day130 m depth, and geological processes were exactly the same as current ones.

The relict sands generally guarantee an increased availability of large volumes of sediment (millions of cubic metres) and their composition is potentially very similar to that of recent beaches; the use of great volumes of this material also has economic advantages.
To move protection activity from a rigid conceptual system towards a resilient one, it is necessary to create the possibility of access to large quantities of sedimentologically-compatible deposits which need regional regulation and storage areas to regulate the first intervention and subsequent refilling of nourished beaches over a period of time.

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Third beach nourishment project with submarine sands along Emilia-Romagna's coast: geomathic methods and first monitoring's results

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Emilia-Romagna's coast is a great naturalistic and economic asset, with considerable tourist attractions, it is among the top summer locations in all of Italy. The coast of the region consists of 110 km of low and sandy beaches which go from the beach of Cattolica to the mouth of the Po river in Volano (Comacchio), and by the barrier-lagoon system in Sacca di Goro(Figure 3).

The shoreline of the region is characterized by erosion's phenomenon, which depends on many factors, both natural and anthropic, such as wave conditions, subsidence, sediment transport, human activities, and climate change. Today Emilia-Romagna's coast is protected by 75 km of hard structures (breakwaters, seawalls, low crested structures, submerged sandbag barriers and groynes), made starting in the first half of the '900 (Arpae, 2016). The regional coastline has stiffened by the presence of these structures, which are largely diffused especially in the southern provinces (Perini, 2008) and tend to modify the topo-bathymetric profile of the beach and the sediment transport.

At the beginning of the '80s, Emilia-Romagna Region adopted the "Project for the protection of the Adriatico emiliano-romagnola shoreline - Piano Costa 1981", this document suggested nourishment intervention as an alternative of the construction of hard defense structures. A nourishment intervention consists of the replacing of sand on eroded beaches, this intervention can guarantee the security of these areas obtaining a stronger beach system, thanks to the height's raising and the sandy shore's enlargement. Moreover, the reconstitution of the beach assures proper spaces for tourist and bathing activities.

One of the first techniques consisted in taking sand from inland borrow areas and transporting it with trucks to the beach, with highly negative impacts on the environment.

In 2002, Emilia-Romagna Region carried out the first beach nourishment intervention on a regional scale, using sands from a submarine borrow area located offshore the regional coast. The sand was carried to the beach with large capacity trailing suction hopper dredges. Thanks to specific monitoring campaigns that constantly monitored the environmental impact and the decreasing of erosion, the Region Authority decided to actualize a second intervention in 2007. Lastly, in 2016, the third intervention of "Security projects through submarine sand nourishment for critical areas of the regional coastline - Progettone 3" was completed.

Arpae defined two coastal state indicators (ASPE e ASE; Aguzzi et al., 2012) in order to describe erosion conditions of each stretch of coastline and the efficiency of the interventions, beach nourishment in particular. This data is useful to represent the complexity of these areas, thanks to its integrated approach. ASPE indicator identifies real critical issues, like the impact of erosion on the coast, thanks to its approach which considers not only the beaches' state in the acquisition's time (ex. coastline variation and sand volume variation) but also the interventions (beach nourishment, hard structures, withdrawals) and their impacts on the beach's conditions. This indicator represents the hypothetical state of the coast without defense intervention, considering in good conditions areas characterized by accumulation or stability, while bad conditions are identified in areas subjected to erosion or in a precarious state (Table 1).ASE indicator describes the beach's real situation after intervention, realized along the coast by Region Authority and Local Administrations, and it classifies coastal stretches into 3 categories: accumulation, stability, and erosion(Table 2).

In 2012, without defense interventions, studies show that 37% of regional beaches were subject to erosion, 28% were in a precarious state and only 35% in good conditions (Figure 4). Considering the defense interventions, studies show a decrease in erosion, with 29% of beaches in a state of erosion and 71% considerable in good conditions (Figure 4). Almost all of these improvements are due to beach nourishment interventions done on the coast and these results confirm the efficiency of Emilia-Romagna's defense policies (Arpae, 2016).

The nourishment intervention of 2016, named “Progettone 3”, was realized between the end of March and the first half of June, in just 78 days. It results the most important intervention along Emilia-Romagna’s coast, in terms of sand volumes and technical and economic resources involved (Figure 5).
The activity involved 8 beach areas in a critical state: Misano Adriatico, Riccione Sud, Rimini Nord e Igea Marina, Cesenatico Ponente, Milano Marittima Nord, Lido di Dante Sud, Punta Marina e Lido di Spina Sud; with a total extension of more than 12 km of beach. The total volume of sand involved was about 1.6 million cubic meters, of which 1.4 million coming from a submarine borrow area and the remaining part, destined to Lido di Spina, from sediments accumulated in the Logonovo’s river mouth(Figure 3and Table 3).The material was carried by sea from the submarine borrow area to the beach, using dredges and pipelines.
The nourishment led to an increase in the beaches’ height of 1.0-2.0 m and a growth of the coastline of 40-65 m.
In order to evaluate the beach’s changes in terms of profile and coastline variations, impacts on withdrawal areas and intervention efficiency a monitoring plan for the years 2017 and 2018 has been take on place. Beach monitoring involved a wider area than the one involved in the sand nourishment: this fact allowed to evaluate the sediment transport as well.
The monitoring, designed by Arpae - Coastal Monitoring Unit, required the survey of over 200 km of topo-bathymetric profiles and the collection of 123 sediment samples on about 20 km of emerged and submerged beach. In the withdrawal area, the bathymetry of an area of 1.4 km^2 was measured with a *multibeam echo-sounder* system (Aguzzi et al, 2017).
Comparing surveys performed before and after the nourishment by the Work Management Department, with those related to the first monitoring, done on November 2017, it was possible to evaluate as a first analysis the morphological evolution of the beaches involved and the efficacy of the intervention itself. After about 18 months from the intervention, a variation of the beach profile, characterized by the migration of the sand both towards deeper depth and along the coast is observed in each beach.
Four beaches are characterized by material losses of about 10-30%, other 3 have lost between 40-60% of the material and only one has lost more than 90%. No direct correlation between the sediment loss rate and the kind of hard defense structure was found in this study (Figure 6).
It must be stressed that the material eroded from the beaches is not lost at all, because it nourishes both the shoreface, which has an active functionin defending the beach from wave’s attack, and adjacent beaches.
These evaluations on the intervention effectiveness are based on the comparison between topo-bathymetric surveys realized in the emerged and submerged beach areas and in different times. In the emerged beach, measures are executed using a GNSS instrument along sections which are orthogonal to the coast. RTK and NRTK are the most common modes: they are both based on a real-time acquisition and they enable you to reach centimetric or sub-centimetric precisions.RTK mode requires the presence of two receivers (*master* and *rover*) and a data transmission system between them. NRTK mode enables you to work with only one receiver during the measures, thanks to a paid service which is connected to a permanent stations network. In this case, it is possible to work within distances of 60 km, higher than the RTK mode which imposes *master-rover* distances of about 10-15 km to obtain centimetric precision. However, we have to consider that the precision tends to decrease in the external areas of the network (ex. coastal areas), even for the NRTK mode.
In the submerged beach area, a precise *echo-sounder* coupled with a navigation unit (composed by a GNSS and an inertial measurement unit) was used. This combination allow to estimate, at any time, the position of the seabed taking also into account the attitude of the boat. Also in this case, we can obtain centimetric precisions. *Echo-sounders* are divided in two types, the *single-beam* which works using only one sound impulse and therefore obtains a point by point relief below the boat’s trajectory; the *multi-beam* which releases hundreds of impulses and is able to survey a depth band with a centimetric resolution.
Measurement preciseness and consequently the processing of digital terrain models (DTM), the accumulated and/or eroded volumes computation, the evaluation of changes in altitude and coastlines, all depend also on the presence of a good geodetic reference frame which have to be well defined and stable as much as possible.

In 2016, a new geodetic infrastructure, the Coastal Geodetic Network (RGC, https://arpae.it/cartografia/), was realized along Emilia-Romagna's coast in collaboration with the Coastal Monitoring Unit of Arpae and DICAM of the University of Bologna, in order to satisfy the requirements of morphological coastal monitoring (Gandolfi et al., 2017).
In this study, it was also possible to observe the consequences due to a not rigorous geodetic datum definition, both from the scientific and economic point of view. This particular evidence support the importance of a geodetic network for monitoring purposes despite the availability of services and augmentation systems that formally allow to make topographical survey without the needs to refer the survey to a classic geodetic network. In the specific study of a beach, profile elaborations showed the presence of a fixed *bias* of about 15 cm in height between first and second plant surveys in an area that was not affected by the sand nourishment. This error produced an overestimation of sand volumes equal to 50.000 m^3, which, at the median price of about 12 Euro/m^3 of sand coming from submarine borrow area, implied to an increase in economic terms of about 600.000 Euro.
In conclusion, coastal erosion's phenomenon emerges as an important problem for the regional coast. Among the different defense works, beach nourishment appears to be certainly the one to prefer; it must be supported by monitoring activities in order to evaluate its efficiency. The monitoring itself requires reliable and comparable measures, based on a common reference system; this system needs to be suitable for the required purposes, to obtain correct considerations on the volumes of accumulated and eroded sand, and, consequently, on the price and efficiency of the intervention.

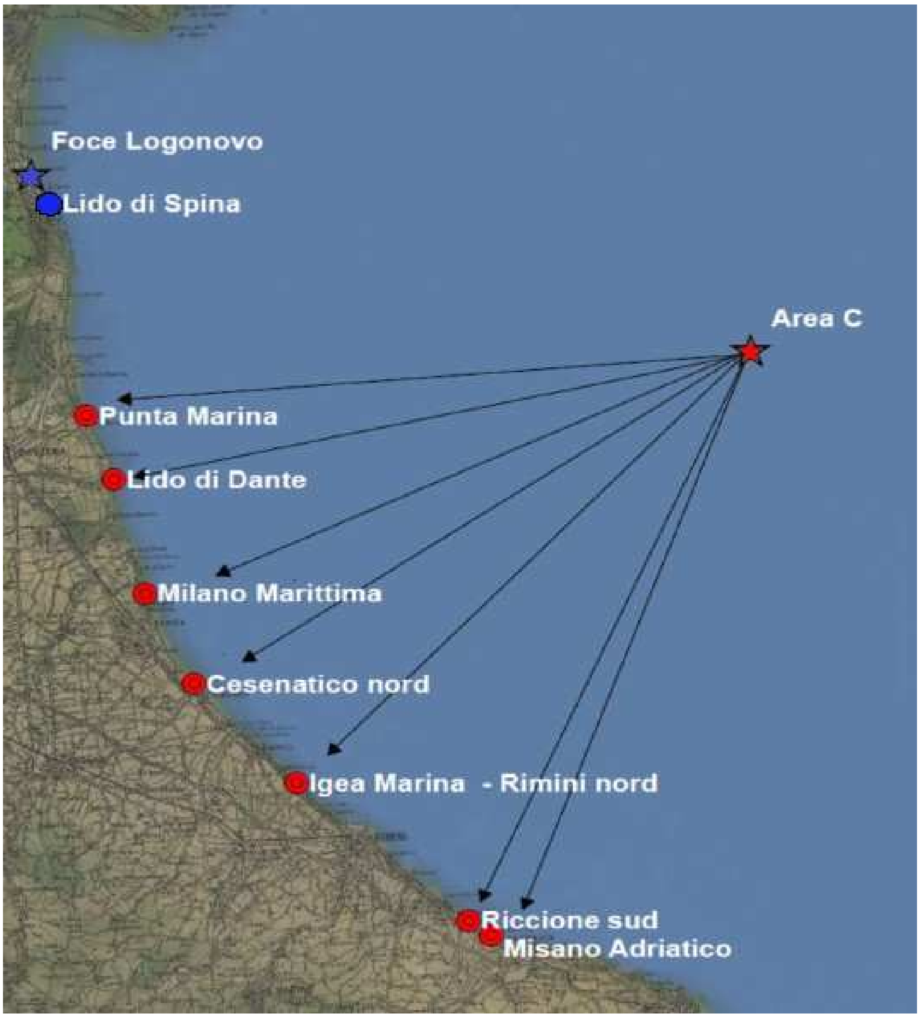

Figure 3- Third nourishment intervention with submarine sands along Emilia-Romagna's coast: sand extracting area and beaches involved in the nourishment(M. Guida et al, 2016, modified).

Table 1 – Classification according to ASPE indicator (Arpae, 2016).

ASPE class	Definition
Accumulation	Coastal stretch which shows significant sand accumulations in the period under review
Stability	Coastal stretch which doesn't show significant losses or accumulations of sand and which wasn't subjected to defence interventions (nourishment or hard structures) in the period under review
Precarious	Coastal stretch which doesn't show significant losses or accumulations of sand and which was subjected to defence interventions (nourishment or hard structures) in the period under review
Erosion	Coastal stretch which shows significant sand losses in the period under review

Table 2 - Classification according to ASE indicator(Arpae, 2016).

ASE Class	Definition
Accumulation	Coastal stretch which shows significant sand accumulations in the period under review
Stability	Coastal stretch which doesn't show significant losses or accumulations of sand in the period under review
Erosion	Coastal stretch which shows significant sand losses in the period under review

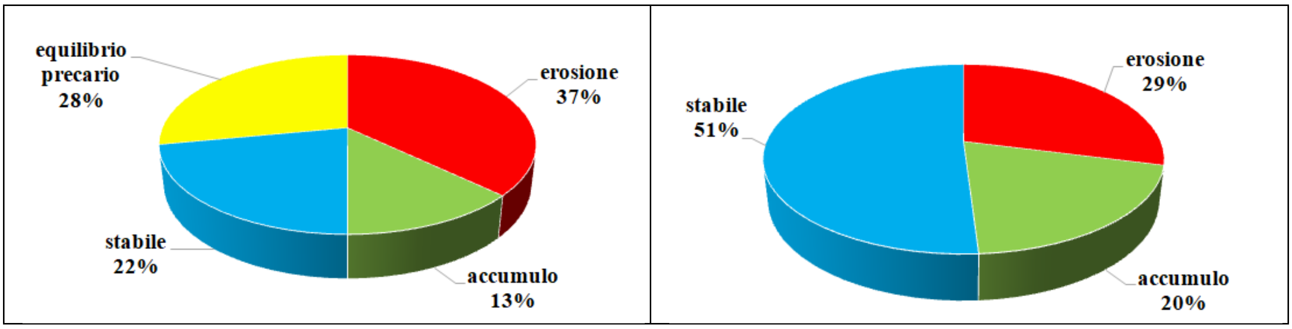

Figure 4 - State of Emilia-Romagna's coast as it would appear in 2012 if no defense interventions were carried out in the period between 2006-2012 (ASPE, on the left), and after the realization of defense interventions (ASE, on the right).

Figure 5- Nourishment intervention of 2016: the trailing suction hopper dredge (top left), the pipeline(top right), a nourishmentyard (bottom left), the beach of Lido di Dante after the nourishment (bottom right).

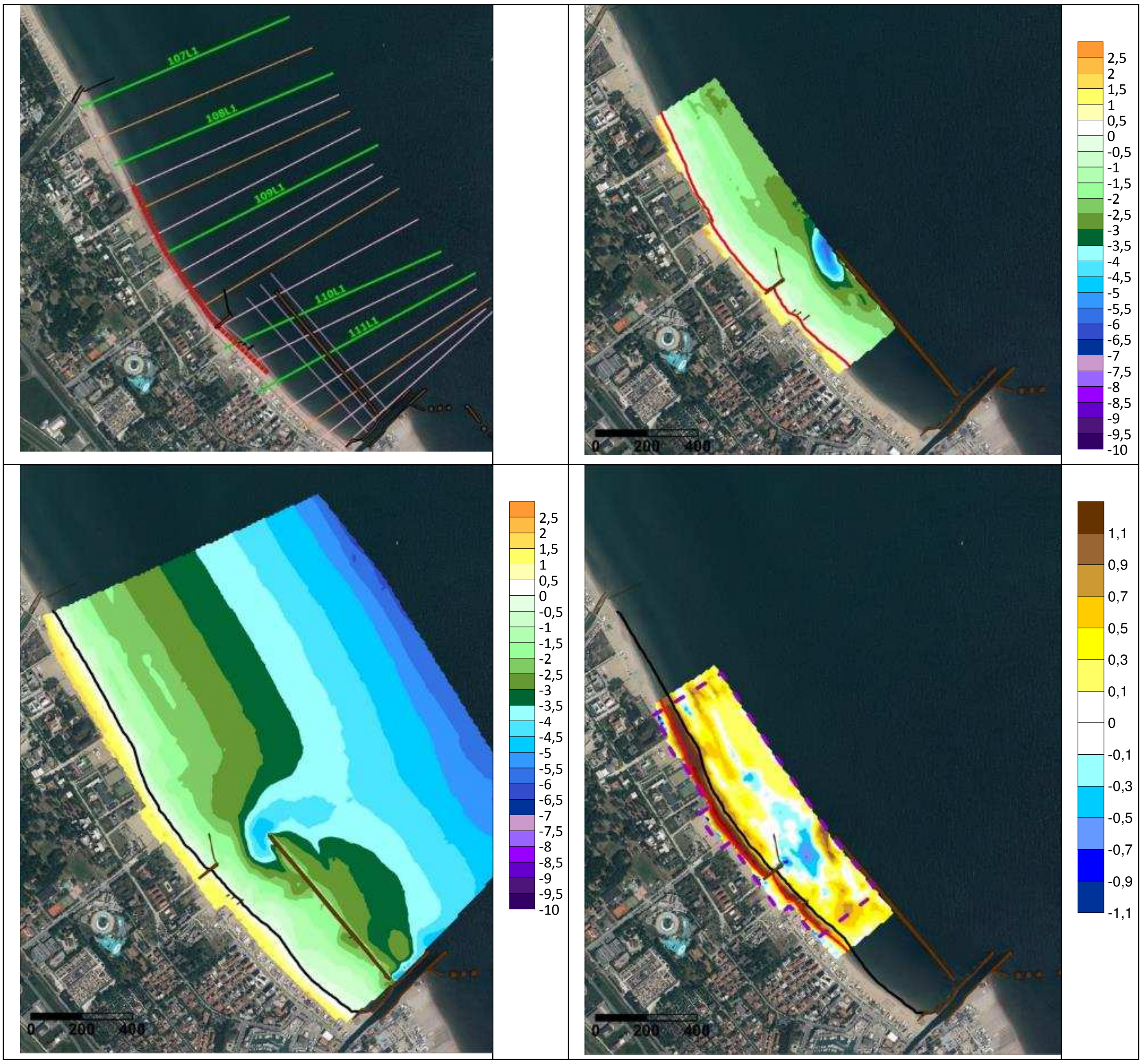

Figure 6- Cesenatico Nord: topo-bathymetric monitoring project (top left), first plant bathymetry (top right), bathymetry of November 2017, first monitoring (bottom left), height's variations between the first plant and November 2017 (bottom right), legends figure in meters.

Table 3: Sites interested by the nourishment, designed and nourished sand volumes.

	Site	Stretch lenght (m)	Designed volume (m^3)	Nourished volume (m^3)	Unit volume (m^3/m)
1	Misano Adriatico	1.550	195.000	221.500	143
2	Riccione	1.400	165.000	212.200	152
3	Igea Marina	1.500	134.200	220.200	147
4	Cesenatico	1.100	115.000	141.030	128
5	Milano Marittima	1.600	180.000	228.530	143
6	Lido di Dante	1.250	110.000	122.050	98
7	Punta Marina	2.500	222.000	249.780	100
8	Lido di Spina	1.340	148.000	199.640	149
	Total	12.240	1.269.200	1.594.930	

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POSTER

Systemic re-vision of coastal morphodynamics

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Worldwide coastal erosion is a topic of increasing impact. Coastal erosion in EU area is becoming a significant environmental, economic and social problem as its effects regard more than 20,000 km of coastline.
According to literature (USACE, 2002), the movement of sediments along the coast is mainly due to the effect of wave-motion. Such model implies that the movement of sediment is caused by the wave-motion component parallel to the coast.
The direction and quantity of the moved material are determined by the angle between the waves direction and the beach and by their kinetic energy.

On the basis of this general principle, mathematical models have been developed to explain the erosion phenomenon regarding beaches. These models consider the reflexions and refractions of the wave-motion when obstacles are present on the coastline and forecast the effects on the shoreline and the seabed. This principle has inspired still today the planning of interventions aimed towards the reduction of the kinetic energy of waves. In order to do this, breakwaters are usually used in order to reduce the wave-motion or directly contrast the transportation of the sand along the coast with groynes perpendicular to the shoreline.
The protection of the coast with hard structures therefore, had the main goal of contrasting the wave-motion by reducing its kinetic energy.
In general, realization of protection structures have produced counter-productive effects over the medium-long term. Although the longitudinal transport of sediment along coast is a well-known phenomenon, it lacks of a deep and systemic analysis regarding dynamics and energies involved in shallow water nearshore.
Nowadays a mathematical (and physical) model taking into account the real morphobatymetric variations due to the coastal bottom current is still missing. In particular, to the best of our knowledge, such a model validation based on long time data set has not be yet treated in literature. Bascom, 1953; Komar and Inman, 1970; Dean, 1973; Stive and Wind, 1982, analysed the wave radiation stress in the nearshore region establishing a link between the driving longshore current and related sediment transport. About shoreline evolution and nearshore morphodynamics, Stephenson and Brander (2003) pointed out that synergistic studies incorporating specialized knowledge of field measurements, laboratory and numerical modelling skills are unfortunately few and they should be further developed. Large-scale coastal evolution analysed by Schwarzer et al. 2003; Cipriani and Stone, 2001, represents one of the most complex areas of research in coastal geomorphology. Probabilistic approaches were first applied to coastal research by Vrijling and Meijer (1992), and Reeve and Fleming, (1997) assessed that stochastic modelling in coastal morpho-dynamics is preferable in respect to a forecast based on dynamics deterministic models.
In recent years, new approaches to coastal hydrodynamics have outlined furtherly the deterministic limits of classical modelling. Amoudry and Souza (2011), underline that numerical models of sediment transport are based on semi-empirical relationships, which are characterized by significant predictive uncertainty. Michaud et al. (2012) suggested to combine a Three-dimensional modelling of wave-induced current with a sediment transport model. Margvelashvili et al. (2012) underline the importance of observational data because of the high complexity of sediment dynamics and limited understanding of key sediment processes. Radermaker et al. (2017), have highlighted how the presence of complex nearshore sand bar patterns (i.e. alongshore bathymetric variability) has an impact on local currents.

In Italy the last official publication by Environmental and Sea Ministry (Tavolo Nazionale sull'Erosione Costiera, 2016) highlighted that in the last decades many scientific problems concerns coastal hydrodynamics are still open especially regarding numerical solutions for turbulent fluxes. The document, moreover, stressed on the fact that there are too much simplifications due to a big complexity of coastal dynamics also in bi-dimensional models and in laboratory tests. In addition the report claims that the use of three-dimensional models which take into account the deterministic form of all the phenomena involved is unsafe for long time

previsions regarding wide coastal application. The main limitations seem to be related to the correct description of turbulence induced by the breaking waves and the mechanism for the transport of the bottom sediment.
Many documents describe the increasing of coastal erosion in Europe (European Commission,2004; Pranzini and Williams,2013) and in Italy (De Marchi,1970; CNR,1986; ENEA,2003; Pranzini,1994; GNRAC,2006; Tavolo Nazionale sull'Erosione Costiera,2016; Pranzini, 2017).
In Italy in particular, the intervention procedures and the typology of the work carried out up till now have not solved the problem of erosion which has instead continued to increase despite the hard structures already accomplished. The degree of artificialization of Italian coasts is one of the highest in Europe as strictly depending on projects realized in an emergency framework, thus highlighting the lack of intervention plans and their functional supervision over time. Looking at official data about coastal protection in Italy, we have assessed that in the last 50 years more than 1,300 km of hard structures alongshore have been built. Moreover, despite beach nourishment accounting for more than 35 million of cubic meters of sand, the coastal erosion length – in the same territorial context - have increased from 600 km to 1,400 km.
Without a deep knowledge and analysis of the hydrodynamic coastal context, the project of coastal protection (which up to now has costed to Italy a global sum estimated around 4,5 billion euros) could be useless or even worsen the coastal erosion.
The twenty-five years monitoring campaign undertaken on the Emilia-Romagna coast seabed by the geologist Giancarlo Faina, has shown the presence of well-located erosive actions that happen parallel to the beach having the geometrical shape of a river route that runs under the coast (Fig. 1).

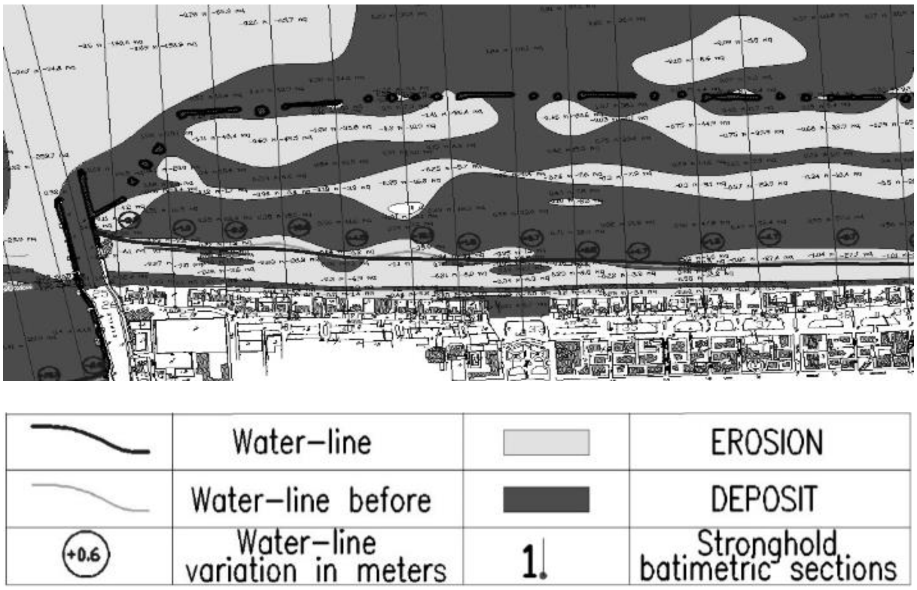

Fig. 1. Example of an erosion-deposit differential map

The analysis unveiled the presence of a real current (influenced in its direction by the Coriolis law) whose planar components move in the clockwise direction (in the Northern Hemisphere) while its vertical component head towards the seabed.
According to the monitoring performed in long stretches of the Marche and Emilia-Romagna coast, the general circulation of this bottom current seems to develop over an order of magnitude of hundreds of kilometres.
This bottom current is normally located among the submerged dunes and the shoreline. The presence, on the coast, of obstacles opposing to the main flow of the bottom current (groynes, piers, ports, barriers, etc), modifies the linear development of the current itself, creating local inclinations that skirt such obstacles. Assuming that the bottom current is the main element that is responsible for the longitudinal solid transport, then a new broad range of studies may be developed.
Many phenomena that are difficult to explain by the effect of waves-erosion only are now easier to understand. With this new hypothesis, the hard structures result to be the cause of inclinations and acceleration of the bottom current and are even responsible for erosion phenomena that can deploy even at great distance from the structure itself.

During the coastal storms, this current acquires a remarkable consistency with an associated speed capable of carrying away the sandy and/or pebbly material determining
a dynamic evolution of the morphology of the seabed. The bottom current locate itself in different flow-lines among the shallows. The shape of the seabed and the position of the submerged dunes are decisive for the dynamic balance of the coastal line. It's well known that the submerged dunes get close to the shore during the summer months (Fig.2a) while in the winter months they move towards the sea (Fig 2b).
In the summer season the submerged dunes are closer to shore and the bottom current passes on a minimum hydraulic surface while the winter period, coastal storms increase the speed of the bottom current.

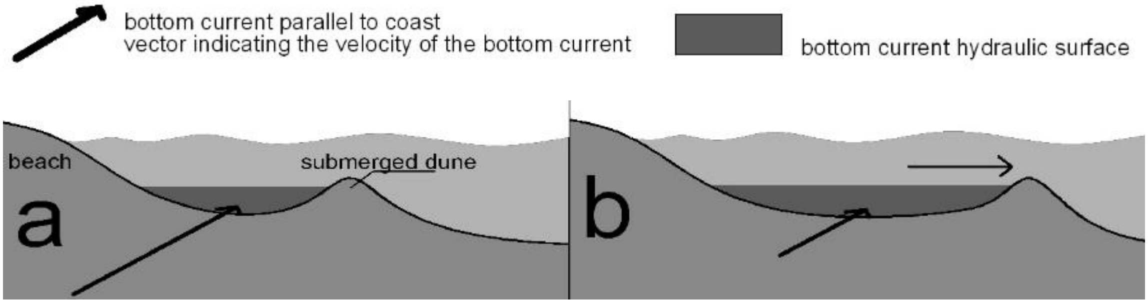

Fig. 2. Morphodynamic of coastal seabed with the bottom current

Data confirm that during a coastal storm, the seabed current's speed increases remarkably, and consequently the possibility of carrying sands.
The increasing bottom current speed moves the submerged dune seaward producing an enlargement of its hydraulic surface and an increase of transported sediment. Then the slowing down effect of the bottom current causes a decrease in solid seabed transport.
The sea then finds a natural equilibrium through the movement of the seabed responding to the different seasonal energetic balances. With the construction of any hard structure there is a tendency to remarkably limit such a natural balance transforming the system from dynamic to static. A static system accepts moderate changes implying that any attempt to increase the width of the beach artificially (e.g. through nourishments) have a great chance of failing as the true cause of erosion is still acting. On the contrary, if the seabed and the dunes are free to move (dynamic system) they will tend to settle down conforming to the new balance with the greater change of maintaining the new artificial beach (resilient effect).
The shape of breakwaters parallel to the beach (such as those in South Riccione and in Misano Adriatico) led to a decrease of the kinetic energy of the wave-motion. Such breakwaters produce the hardening of the whole system no longer allowing for the natural movement of the shallows when the energetic conditions of the coastal bottom current change. The anti-erosion barrier turns to be the cause of the erosion itself. The hard structures planned to stop the wave-motion, regardless of the bottom current, will produce adverse effects of both environmental and economic nature.
The interventions that can be carried out by considering the systemic approach here represented can solve many problems often interrelated to each other: from the silting up of ports to the coastal erosion. The improvement of the bathing waters and the aesthetic of the waterfront are granted as secondary, but important effects of the main issue just cited.
The regular surveying of bottom current dynamics makes possible to plan interventions to restore beach equilibrium by implementing a monitoring/maintenance system that reflects the natural resilience of the coastal environment.
This approach, which invokes a unitary vision of coastal environment, working with the aim to increase the beach natural resilience, lowering in the meantime the general entropy of the environment.

Marine coastal water quality and bathing tourism: impact of submarine springs along the coast of southeastern Salento (Apulia region, Italy)

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Introduction

Marine coastal areas are ecosystems characterized by high biological diversity and productivity; therefore conservation of these environment and their internal equilibria are the main goals of economic and social development policies of each country. The main human uses of marine environment are represented by recreational activities and its exploitation for food purpose.

The awareness that urban waste pollutions and in some cases industrial waste could affect the use of resource, led public health authorities to analyzed the related hazards linked to this problem. Marine coastal waters aimed for recreational purposes are significantly increased during the last years, particularly in tropical and subtropical geographical region, due to a combination of developmental socio-economic factors. More attention was given to aquatic environment, specially the marine one, as recreational use. The rapid and uncontrol development of marine coastal areas to face the tourism lead to a deterioration of water quality, characterized by a pollution ranging from modest to severe, due to an increase of urban waste. Tourism has contributed also to a huge diversity of pathogen microorganisms found in waste water discharged into the sea; this led to an increase of the incidence of diseases between local and tourist populations. This increase was related, in different way, to the bathing in pollution marine waters. Progress in the use of marine environment for recreational purpose, enhance the possibility of enjoying marine water compared to the traditional use as bathing and swimming. Other activities (surf, underwater fishing, canoeing, etc…) becoming increasingly widespread, leading to a necessary improvement of the monitoring of quality. At this purpose, it was observed a long term duration of the period of use of marine water attractiveness compared to the normal bathing season (from May to September); furthermore, these activities imply an increase of contact with these water. It suggests the development of new procedures for risk assessment to different type of exposures related to the diversity of recreational activities.

Despite the traditional monitoring present methodological limit in relation to the definition of the quality state of the environment, over the last few years, there is a requirement to combined traditional monitoring system with additional indicators; these could allow to better establish risks to marine organism and human's health, starting from the identification of the intrinsic "vulnerability" of the environment and of "hazards" detected in some pressure factors. One of the main effective strategy to analyzed the infective risk assessment linked to recreational activities in marine coastal water, could be an integrate approach which bring together a wide range of aspects: physics and hydrological characteristics of the area, anthropogenic characteristics, in particular to demographic, productive and epidemiological aspects which highlight potential hazards as outbreak diseases and source of pollution; lastly monitoring of the ecological and hygienic sanitary characteristics.

The aim of the present study is to identify potential factors which can be responsible to the alteration of the ecological quality of marine coastal waters along the protected area "Costa Otranto - Santa Maria di Leuca e Bosco di Tricase Regional Nature Park" located in the eastern part of Salento Peninsula. The Park (established by Apulia Region with Regional Law n. 30/2006) covers a surface of 3,227 hectares, and with an area of about 57 km represents the biggest among the regional parks established in the province of Lecce. Twelve municipalities belong to it: Alessano, Andrano, Castrignano del Capo, Castro, Corsano, Diso, Gagliano del Capo, Ortelle, Otranto, Santa Cesarea Terme, Tiggiano and Tricase.

Material and methods

The cause-effect relation linked to possible environmental alterations, along the South eastern coast of Salento, was studied with DPSIR framework model. This model allow to understand the relations between human and environmental activities. According to DPSIR, indicators where choose on the base of their potential to influence the quality of deep groundwater. Socio-economic factors are the driven forces (D) applying pressures (P) to the environment, leading to changes in state (S) conditions as consequence. These factors produce impacts (I) on human's health and on ecosystems. Response actions (R) expected, can affect directly the environment, on the impacts and on driving forces. Therefore, a total of 32 indicators were selected to describe different aspects of environmental systems, in order to obtain useful information for the management of marine coastal waters.

At this purpose, were considered the following aspects:

Demographic, social and economic aspects (Driving forces);
trends of environmental exploitation and production of pollutants (Pressures);
quality state of bathing waters - physic-chemical, microbiological and ecological parameters - (State);
public and ecosystems' health linked to the quality of the environment and to social and economic aspects (Impacts);
actions (local policies, environmental research funds, environmental education, environmental protection strategies, etc…) suggested to reduce or prevent negative impacts, to correct environmental damages or for environmental sources conservations (Response);
The value of each indicators, was compared with reference point in order to address a quality assessment which indicate environmental condition described by the same indicator.
The assessment was expressed by symbols which correspond to environmental quality situations reported in Table 1.

Table 4. Addressed judgments to each indicator of the DPSIR model taken in consideration.

Symbol	Quality assessment
	Good. Optimal environmental condition extended at long term.
	Sufficient, but with negative trend especially if associated with adverse factors.
	Negative. Immediate risk for the environment and to public health which benefit of environmental sources.

Socio-economic aspects were evaluated through data collection made available from municipality belonging to the study area or from other institutions, whereas bathing water quality assessment was carried out through water monitoring. This activity was performed by periodic sampling of water from 30 different points identified in relation of different risk factors along the coastline between Otranto and Leuca (Figure 1).

Figure 7. Location of the sampling sites along the coastline Otranto-Leuca.

In each site, were collected water samples for microbiological analyses to research the waters quality indicators (E.coli and Enterococci) and other alternative parameters (total heterotrophic bacteria and luminescent fraction), useful to give important information to human's health risk. During sampling, physical parameters were also collected (temperature, pH, salinity).

Moreover, it was defined the trophic index TRIX (Trophical index for marine systems), which account the main components of marine ecosystems which characterized primary production: nutrients and phytoplanktonic biomass. It holds in a numerical value a combination of some variables (dissolved oxygen, chlorophyll "a", total phosphorus, dissolved inorganic nitrogen) which determine within a scale of values ranging from 1 to10, the trophic condition and productivity levels of costal areas.

Result and discussions

In this study, data collected allowed to select in the study area different vulnerability's classes, with an high average value due to the presence of a karstic aquifer index of protection very small, along all the study area.
The state of quality of marine coastal waters seems to be within the limits of the existing legislation (D.Lgs n. 116/08). Data analyses, related to the period of study between February and May, showed an hygienic state of bathing water optimal with a punctiform localization of contamination by fecal indicators. In June, microbiological state was characterized by high values widespread at large part along the coast.
The main area characterized by microbiological contamination include, in particular, waters of the municipalities of Otranto, Diso, Gagliano del Capo e Tricase; whereas, some coastal areas belonging to the municipalities of Andrano, Castrignano del Capo, Corsano e Tiggiano showed a good quality of coastal waters, registering always negative viable counts. Analysis conducted showed the overall presence of indicator of fecal contamination particularly in that areas characterized by submarine springs. Statistical analysis, mainly the linear regression between salinity and fecal contamination indicators, verify the hypothesis of the contamination dependence from groundwater pollution. This aspect is probably linked to urbanization and to unsuitable treatment of sewage from public origin, as it was found from data of pressure. In contrast, where salinity was high and urban development was not significant, the concentration of indicators appears low or null.
Data analysis of the heterotrophic bacterial components, registered higher values during summer season, in sites located near to submarine springs. At the same sites, fecal contamination appear higher probably due to an addition of organic material. The increase of epibacterial component was explained with the releasing of organic material in marine environment which led to an increase of growth rate and of the biomass of heterotrophic bacteria. While, the luminescent fraction did not show any significant relation with inputs detected but only with water temperature, confirming the high sensibility of these bacteria to seasonality.
TRIX values obtained highlighted a low trophic state in the main part of the analyzed sites; it refers to very productive waters with an high trophic level. The obtained results can be related to the presence of anthropic pressure, linked to bathing tourism and wastes treatment from urban area, being during summer season unable to sustain the strong touristic inflows.

Conclusions

Marine coastal waters of the study area, due to particular morphological and geological conditions and to the presence of pressure factors punctual and widespread, are interested by fecal contamination. Inputs of pollutants are higher near to the submarine springs site.
Therefore, a well structured program management along this coast is required, in particular for submarine springs, in order to reduce pollution load and prevent the risk of infection linked to the recreative use of the waters which appear contaminated by wastes. Management actions plan realized until know were not sufficient to protect properly quality of groundwater responsible of submarine springs pollution, and as consequence, contamination of marine coastal water. Moreover, municipality data reported a still high number of dwellings not connected to sewage system; in fact, the balance of the potential sewage system and the anthropogenic load, is negative. The percentage of separate waste in the municipality aim of the study, is really low and far to achieve the planned goals.
These circumstances require the immediate adoption of measures to reduce pollutant loads derived from anthropic activities in the area. It is necessary to reverse the contamination by adopting minimum standards of environmental quality and implementing policies to maintain the objectives achieved.
Specifically, the main safeguard measures should seek to:
improve the systems of disposal and treatment of wastewaters, allowing the use of public sewage system, if present and improving the sewer line eventually;
monitor more closely the construction, location, size and use of septic tanks to prevent pollution caused by the dispersal of the wastewaters they contain;
In addition, it should be important to have deep knowledge about any other pollutant present in marine coastal waters and indirect pollutants coming from groundwater through a continuous bathing water monitoring, in order to obtain an exhaustive overview of the existing cause-effect relations.

Monitoring the evolution of the coasts for a sustainable Blue Growth

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The Earth is mostly covered by water. About 70% of its surface is covered with oceans, seas, rivers or lakes. Furthermore, 90% of man made goods or their components are shipped by sea.
Today the statement should no longer be the blue economy, but that the economy is blue.
Accordingly, today the main challenge is not to use the sea, because we are using the sea for transportation, fishing, mining and a lot of other economic activities. The challenge is to reduce the pressure on the sea.
The Coastal Zone is an extremely complex area due to its anthropogenic and natural components and, at the same time, it is vulnerable and exploited for environmental, economic, social and defense interests.
We are simply over-fishing, over-transporting, over-exploiting, not taking into consideration what the micro-economic science studied decades ago, the externalizations. The cost of our activities is deeply connected with pollution, gas emission, long term preservation of living and not living resources at sea.
One of the basic points in the marine environment that has evidence from the facts, is that we have underestimated the impact of our activities, and before trying to predict the future behavior of the marine environment and managing our future sea related activities, we have to know how the marine environment works. One of the main challenges is to study the sea as it is and its possible evolution, because the sea affects humans and will affect their future on the Planet.

The United Nations have proclaimed the Decade of Ocean Science for Sustainable Development (2021-2030) to support efforts to reverse the cycle of decline in ocean health and gather ocean stakeholders worldwide. One of the two objectives is to "Provide ocean science, data and information to inform policies for a well-functioning ocean in support of all sustainable development goals of 2030 Agenda".
The European agenda on the Ocean Governance is founded on the same idea. It is "Reducing pressure on oceans and seas and creating the conditions for a sustainable blue economy".
The United Nations, in 2014 set the Sustainable Development Goals of its 2030 Agenda, and Goal 14 is "Conserve and sustainable use the oceans, seas and marine resources for sustainable development".
Taking into account the presence of the externalizations, a strategy to face them is becoming present in the international agendas. Human life on the Planet, in a term longer than a few years, must take into account what the Planet can give us. The balance between humans and the Planet is today a challenge; the strategy to manage it is the idea of sustainability, the key driver present in the international agendas.
Historically these interests are related to the Hydrographic world, which deals with the study and representation of territory and its evolution especially in the field of maritime navigation.
Hydrography is defined by the International Hydrographic Organization as "the branch of applied sciences which deals with the measurement and description of the physical features of oceans, seas, coastal areas, lakes and rivers, as well as with the prediction of their change over time, for the primary purpose of safety of navigation and in support of all other marine activities, including economic development, security and defense, scientific research, and environmental protection". Its aim is to study the physical features of the marine environment from the past into the future. This description of the Oceans, which is realized by data, is used for all marine activities. Data gathering at sea is a very expensive activity, and should be oriented to data quality rather than data use as it was in the past.

The Italian Navy Hydrographic Institute (hereinafter IIM), representing Italy in international hydrographic Committees and Organizations such IHO (International Hydrographic Organization), is heavily involved in the survey of the Coastal Zone, where safety of the navigation appears critical.
In the last decades the focus on the coastal zone has been increased not only by the local authorities, who are in Italy responsible for the management and protection of these areas, but also by the central Environmental Ministry that is involved in European Environmental Policy. For this reason a number of European Directives have been promulgated about environmental protection and study of territory, such as INSPIRE, Marine Strategy, and most of them are oriented to the integrated coastal zone management.
The integrated coastal zone management (ICZM) is the modern approach used in the study, management and exploitation of coastal areas in various applications, as in coastal areas there are interests concerning the most different fields, economic, environmental, legal, scientific and social. They are inherently unstable by nature and consequently must be subject to a continuous monitoring and updating of its variations and trends. Coastal

areas are a portion of land, emerged and submerged, containing the shoreline and are subject to both continental and marine geomorphic processes. The shoreline is the clearest expression of how this sector is particularly dynamic. Proper analysis and representation of the shape and nature of coastal areas are a first step to provide reliable and comparable tools to those who study and manage them.
Data are the result of a measurement process, as stated by the Bureau international des poids et mesures in the Vocabulary of metrology they are the “quantity values that can be reasonably attributed to a quantity”. These quantity values, which can be many for one aspect we want to describe, the quantity, are not only numbers, but they are a combination of numbers and reference. The reference, in the geospatial environment where the sea lays, is not only the unit of measure, but also the whole reference frame in a three dimensional space. Adding the fourth dimension, time, the sea can be studied by data gathering from a four dimensional point of view. Every quantity value is then a result of a measurement activity where the measurement uncertainty, the estimation of all the errors present in the process of measurement, accompanies the number and reference from the first planning of the measurement process.

After the statistical assessment, all quantity values can be referred to the same quantity, which describes different aspects of the marine geospatial environment. These aspects are, for example, the shape and nature of the seabed, water temperature and salinity, the position of the coastline.
Use the same data many times is one of the main challenges about marine data management. It requires collaboration, coordination, cooperation. The same data, referred to a standard reference frame and at a fixed quality level by uncertainty, should be shared by different actors, who are involved in different uses of the sea. This best cost-effective situation can be achieved by common infrastructures, which are web-based services accessible to all the scientific community.
Today the concept of Geo-Databases has been replaced with “Marine Spatial Data Infrastructure” (MSDI), that is focusing on the marine data or information that identifies the geographic location of features and boundaries on Earth and Space (including natural or constructed features, oceans and space, together with their encoding attributes, observations and other metrics).
Many international directives, such as INSPIRE Directive, aim at creating a global spatial data infrastructure for the purposes of the Community (EU in this case) focusing on environmental policies and policies or activities which may have an impact on the environment, and at the same time, at promoting the sharing of environmental marine spatial information through public access to the data.

Knowing with a good resolution the shape of the Earth is a precondition for the success of an economy, which today is blue, balanced at a level which takes into consideration the sustainability. Moreover, a better knowledge of the shape of the seabed, based on the same data, can be used by different stakeholders, particularly in the coastal zone, where the need of coordination among different activities is stronger.
First of all, safety of navigation is better assured, because vessels can clearly define where they can navigate or not. Furthermore, the presence of natural and archaeological features (rocks, wrecks, obstructions) can be better positioned and studied by a better knowledge of the characteristic of the seabed. Secondly, data can be used for Marine Spatial Planning. It is one of the pieces of the marine strategy, and it is a way to plan different activities which are conducted at sea. For example, knowing the depth, Marine Protected Areas can be better geographically placed, preserving the areas where there is an urgent need of rules. Routes for navigation can be planned, creating the so called highways of the sea.
Thirdly, depth in shallow water areas is deeply connected with the erosion of the coasts, because the submerged beach can be better delimitated and managed. In coastal studies the integration of sea data and land data is the key topic. Only by a model based on a seamless vertical datum, a common reference in and outside the sea, can the integrated coastal zone management be achieved.
Depth is an input layer for both monitoring activities, which study the condition of marine environment through the past timeline, and oceanographic models, which study and try to predict water mass circulation.
Today, unfortunately, we know at a good resolution only 15% of the shape of the seabed, and often monitoring and modeling are based on wrong assumptions.

A lot of other different applications can be found, and elevation is only one of the geographical themes that can be studied and monitored at sea. Only a strong combination of them can promote a real scientific study of the sea. And the study of the sea by data is the only way to plan and understand the real past and future complex impact of human activities at sea from a sustainable perspective.

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Long period oscillations of sea level data in Genoa

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Over the last decade, there has been a significant progress in understanding future sea level values as a result of improved satellite and in "situ" observations and numerical models (Chambers et al., 2012). As a result, there is a huge demand for improved projections of sea level scenarios, particularly at local and regional level. At the Thomson gauge of Genoa (44°25' N, 08°54' E) a permanent sea land reference mark is used to measure sea level changes (Lusetti, 1977). A statistical investigation on the mean annual data from 1928 to 2006 has produced a linear positive trend of about 1.1 mm per year (Demarte et at., 2007). In a recent investigation (Papa, 2017) the mean sea level from 2006 to 2016 has shown a positive rate of 10.2 cm compared to the 1937 to 1946 average value which is the standard reference mark for the Italian terrestrial topography. In the present paper we show the results of spectral analyses of long period oscillations of the annual mean sea level data of Genoa from 1928 to 2016. In particular, we have found a significant oscillation with a period of 18.6 years associated with the period of the retrograde orbital motion of the Moon's nodes through a complete cycle: the Moon's nodes are the points where the Moon's orbit intercepts the Earth celestial ecliptic (Schureman,1941).

It is well known that when a periodic force is applied to a linear system the forced oscillation is determined once the system and the external force are given, and is by no means affected by the initial condition with which the oscillation was started. The nonlinear systems, however, can possess a wide variety of periodic subharmonic oscillations whose frequencies are a fraction 1/2, 1/3, ..., of the frequency of the external force (Trefftz, 1926; Mandelstam et al.,1932). Having established four components in the harmonic analysis of the mean sea level data we computed four FIR filters centred at the angular velocities: 0.3376 rad/yr (period =18.6 years), 0.6756 rad/yr (period=9.3 years), 1.0134 rad/yr (period=6.2 years), 1.3659 rad/yr (period=4.6 years).The superposition of the four filter outputs corresponding to the first four harmonics is close to the experimental sea level data in the time interval from 1928 to 1972.

At present our understanding of the mechanism responsible for the development of subharmonic waves in the mean annual sea level values in Genoa is quite limited; nevertheless we make the hypothesis that from 1973 to 2016 nonlinear effects have produced sea level oscillations whose frequencies are a fraction 1/3,1/5 of the frequency of the external force produced by the retrograde orbital motion of the Moon's nodes. The superposition of the harmonic and the subharmonic oscillations significantly reproduces the positive sea level trend of the last decades and this result might play an important role to predict the sea level changes in Genoa over coming years.

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Expeditive coastal flooding scenarios assessment induced by long term climate changes

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The work moves from the results proposed by the SaveMedCoast project (Sea level rise scenarios along the Mediterranean coasts –Anzidei et. al., 2018) and deals with the implementation of expeditive methodologies for maximum super-elevation level (MSL) assessment at 2100, due to combined effects of sea level rising (SLR) and vertical land motion (VLM) with ordinary and extreme storm surge events on the jonian-lucanian littoral, nowadays prone to erosion. Such an assessment is of a great importance in coastal flooding areas extension forecasting in order to assess coastal risk and/or vulnerability scenarios.

Based on the greenhouse forecast The International Panel on Climate Change (IPCC) of the United Nations describes four different Representative Concentration Pathways (RCPs) of greenhouse gas emissions and atmospheric concentrations, air pollutant emissions and land use referring to global warming and sea level increase contained in the extreme scenarios named RCP 2.6 and RCP 8.5 respectively. In the proposed methodology implementation, the mean sea level increase projection at 2100 for the whole Taranto Gulf have been extrapolated for each extreme scenario.

It is well known that Mediterranean coasts are characterized by micro-tidal conditions with respect to the Oceans. Therefore, tides are not so relevant for the evaluation of sea storm conditions, which are mainly characterized by wind wave climate both in ordinary and extreme scenarios. On the other hand, tidal data are important in a general sea level increase, therefore a tidal data analysis was performed in terms of harmonic components by acquiring the principal astronomical constituents and assuming a typical annual evolution implemented by freely available data from The Italian National Tide Gauge Network.

The maritime wave climate assessment and storm surge data for the study areas have been evaluated through the Forecast/hindcast system for the Mediterranean Sea developed by the Department of Environmental, Chemistry and Civil Engineering of University of Genoa (Mentaschi et al., 2013, 2015).

Wave climate assessment originates from a re-analysis of atmospheric and wave conditions, producing an hindcast database spanning from January 1979 till the end of December 2016 over the domain employed for the atmospherical and wave condition simulations.

The system is mainly based on the WAVEWATCH III (WWIII) model in the Mediterranean. This model allows the climate wave analysis referring to several case studies related to heavy storms observed in this basin in the last twenty five years. Wherever available, the simulation results have been validated using buoy data provided by different official sources.

Wind forcing has been simulated using the WRF (Weather and Research Forecasting) model for all the case studies, while the wave simulations are carried out using the WWIII model. The simulated and observed data are compared through statistical error measures like Normalized Bias (NBI), Normalized Root Mean Square Error (NMRSE), also known as Scatter Index, and Correlation Coefficient (CORR). Since model performances are not uniform in space and time, all the statistical error measures have been evaluated taking into account different group of buoys chosen depending on the geographical location in the Mediterranean basin or on the sea conditions (stormy or not stormy).

By the use of wave climate data referring to ordinary and extreme storm wave conditions, in terms of return period (R_T), respectively R_T= 1 year and R_T= 100 years, wave setup and wave run-up were estimated. In the analysis wind set up was neglected. We used the topo-bathymetric information collected by Basilicata Region, to model the above-mentioned physical phenomena.

The implemented workflow starts from the linear wave theory, including wave transformation up to wave breaking to estimate wave conditions during the wave travelling and ends to the assessment of the wave setup and runup on beach. Additional changes in water level include VLM, SLR and tide. The total super-elevation of water levels can be easily reported in a GIS environment to rapidly produce flooding maps by showing the coastline position for different scenarios.

In detail, wave transformation has been performed by using the *Equivalent Snell's low*, the wave height at a location i is related to the wave height in deep water H_0 by

$$H_i = H_0 K_S K_R$$

Where K_S is the shoaling coefficient and K_R is the refraction coefficient caused by the shape of bottom topography which influences the direction of wave travel. When the wave motion interacts with the bottom, celerity and group velocity are changed as is the wavelength. The changes in wave speed change the direction of wave travel and change the amplitude of the wave, these phenomena are known as refraction and shoaling.

In the proposed expeditive assessment, the precautionary assumption that the direction of wave travel doesn't produce refraction is fixed.

Wave height at the incipient breaking H_b is evaluated by the definition of the breaker indexes.

The breaker depth index is defined as:

$$\gamma_b = \frac{H_b}{d_b}$$

In which d_b is the depth at breaking.

Breaker height index, describing the nondimensional breaker height, is defined as:

$$\Omega_b = \frac{H_b}{H_0}$$

Beaker depth index is evaluated by the expression derived by Weggel (1972)

$$\gamma_b = b - a\frac{H_b}{gT^2}$$

For $tan\beta \leq 0.1$ and $H'_0 \leq 0.06$, where T is the wave period, g is gravitational acceleration and H'_0 is the equivalent unrefracted deepwater wave depth. The parameters a and b are determined function of beach slope:

$$a = 43.8\left(1 - e^{-19tan\beta}\right)$$

$$b = \frac{1.56}{1 + e^{-19.5tan\beta}}$$

Breaker height index has been estimated by the relation of Komar and Gaughan (1973) derived from linear wave theory

$$\Omega_b = 0.56\left(\frac{H'_0}{L_0}\right)^{-\frac{1}{5}}$$

Breaker type may be correlated to the surf similarity parameter (or Iribarren number)

$$\xi_0 = \tan\beta\left(\frac{H_0}{L_0}\right)^{-\frac{1}{2}}$$

On uniformly sloping beach, breaker type is estimated by

Surging/collapsing $\xi_0 > 3.3$

Plunging$0.5 < \xi_0 < 3.3$

Spilling$\xi_0 < 0.5$

In the expeditive assessment of coastal flooding areas, the Jonian littoral has been represented by 48 transects representing the whole typical existing morphologies; for each transect, a mean uniform beach slope has been assumed.

As well known, irregular wave runup is a function of the surf similarity parameter (CEM 2008, Mase 1989) and is evaluated by the use of the predictive equations. The runup value adopted in this work is the maximum runup R_{max} defined by the relation below displayed

$$\frac{R_{max}}{H_0} = 2.32\ \xi_0^{0.77}$$

At a global level, the results in the rising sea level assessment coupling meteorological/tidal components and long term elevation changes show a remarkable and generalized land reduction both in ordinary and extraordinary wave conditions mainly caused by the smooth slope of the beach profiles and by the presence of extended low areas above the forecasted mean seal level, behind the existing littoral pine grove and.

Such results are very interesting in terms of potential effects and repercussions on a territory with a strong and increasing tourist and environmental vocation. In fact, on one hand, land reduction in anthropogenic areas raises concerns, especially within the public opinion, could presage to a "throwback" in those places subjected to a large land reclamation works in the first half of the past century. On the other hand, coastal wetlands restoration or creation could lead to increasing biodiversity and to development of new green opportunities for example in integrated water resources management rather than to the ancient sad and malarial swamps characterizing wide areas along the Italian peninsula and in particular the Lucanian littoral.

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Climate change assessment, monitoring and adaptation at trans-boundary level: the EU Interreg CHANGE WE CARE project

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In the recent decades, the advancement in the fields of climate sciences has been strongly pushed forward by the increasing awareness of the extent of climate change and its impacts, as well as by the development and tuning of assessment and prediction tools for the characterisation of such processes. Nevertheless, the integration of the achieved knowledge into efficient and durable response strategies is still challenging, based on the urge to overcome disciplinary and administrative fragmentation. In fact, the incomplete capability of explicitly addressing the complexity of coastal dynamics, the coexistence of different time and space scales, and the presence of possibly competing management needs, often lead decision makers to focus merely on local resources and critical issues, failing to coordinate with (and benefit from) ongoing policies in neighbouring coastal zones. This can lead, if not to the rise of potential conflicts, to a suboptimal exploitation of the available knowledge and tools, whereas a cooperative, synergetic and interdisciplinary approach in the assessment, monitoring and planning activities, allows an optimization of the insight potential and a maximization of the management efficiency.

The Adriatic Sea (NE Mediterranean basin) is characterised by a heterogeneous variety of coastal systems, affected by strong anthropic pressure, and by different physical, morphodynamical and ecological forcings, mutable under the effects of climate change. The Adriatic coastal landscape ranges from low-lying alluvial beaches prone to flooding and erosion and deltaic areas undergoing loss of habitats and biodiversity, to coastal lakes and free-surface aquifers facing salinization issues, all involving a broad spectrum of physical, geomorphological and ecological processes tightly connected in complex interactions. This condition makes the Adriatic Sea an ideal site for developing and testing concerted strategies for a multi-disciplinary assessment of the present conditions and expected scenarios in climate change conditions, as well as coordinated adaptations actions, at a transboundary level. This is the goal of CHANGE WE CARE (Climate cHallenges on coAstal and traNsitional chanGing arEas: WEaving a Cross-Adriatic Response), a Project started in 2019 and funded by the EU Interreg Italy-Croatia Programme with an overall budget of 2.7 M€, involving 11 scientific and administrative partners from the two countries in the cooperation area for thirty month overall duration.

Conceived in close connection with International and National coastal management initiatives (e.g. such as the TNEC – *Tavolo Nazionale sull'Erosione Costiera*, National Coastal Erosion Board, on the Italian side) and coordinated by the Institute of Marine Sciences of the Italian National Research Council (ISMAR-CNR), CHANGE WE CARE fosters the implementation of policy instruments at different scales. In particular, this project tackles the risks affecting coastal and transitional systems in the Adriatic Sea and related to the expected effects of climate change, with a focus on the implications on meteo-marine climate, hydrological regimes, salt intrusion, tourism, biodiversity and land use, aiming at the formulation of integrated and shared planning options for decision makers and coastal communities. The variability of possible geomorphological and ecological settings, physical drivers and threats determining coastal vulnerability in the cooperation area is represented by five paradigmatic pilot sites in which a set of climate change adaptation/management plans will be defined. The pilot sites include two major river deltas (Neretva and Po, respectively on the Croatian and the Italian coasts), a river-bay system (Jadro River and Kastela Bay, Croatia), a coastal lake (Vransko Jezero Nature Park, Croatia), and a large sand bank system (Banco della Mula di Muggia, Italy). Their representativeness of the Adriatic coastal landscape will enable the transfer of successful methods of analysis, development and implementation of adaptation measures to other systems facing different modulations of similar problems at the cross-border scale. Some of these pilot sites are placed in Protected Areas where adaptation/management plans should primarily consider actions aimed at environmental protection and biodiversity conservation.

In CHANGE WE CARE a common methodology is used in planning climate change adaptation measures throughout the Adriatic coast, putting together the elements of present-state assessment, prediction of future evolution (and associated uncertainties), and decision making.

The first phase of the Project will be dedicated to the characterisation of the ongoing natural processes and their recent trends, also in the light of their interactions with the anthropogenic influences, aiming at a quantitative identification of the key drivers of the coastal processes, at the basin scale and with a deeper focus on the pilot sites. The available information will be organised, standardised and shared among the partners, identifying the existing knowledge gaps, initially with a sectorial approach, and subsequently conveying the results into an interdisciplinary view, allowing the description of the main links among the processes and their key drivers. Most importantly, this activity will lead to the definition of common interdisciplinary strategies for a coordinated approach to observation and modelling activities. On a broader perspective, due to the geographical and meteo-oceanographical setting of the Adriatic Sea, an up-to-date assessment of coastal dynamics in this basin will also provide a key element for understanding the processes actually taking place at the Mediterranean scale.

Once the basin-scale dynamics have been characterised and the “causal loops” of coastal dynamics have been disentangled for each pilot site, it will be possible to delineate a prognostic description of the expected evolution of the Adriatic coastal and transitional systems over a multi-decadal scale, accounting for the possible impacts of climate change. Depending on the data availability and on the actual capability of reproducing the physical and ecological dynamics underlying coastal evolution, this goal will be achieved either by means of a statistical extrapolation of the observed trends, or via numerical modelling applications with variable degrees of complexity. At the local scale, stakeholders will be called to play an active role in the identification of the key quantities to be taken into account in the prognostic analysis, thus addressing the scientific activity towards the socio-economical needs of the areas involved. In turn, by means of dedicated training courses, the Project will convey the acquired knowledge to coastal communities and local stakeholders, thus enhancing their awareness on the climate change impacts and their ability in formulating and implementing efficient and sustainable responses. Alongside with projected scenarios of coastal dynamics under climate change, common monitoring guidelines throughout the cooperation area will be issued, fostering the definition of synergetic site-specific monitoring plans. Over a long-term perspective, the additional information continuously supplied by such plans will allow to reduce the uncertainties intrinsically affecting the projected scenarios, and to adjust the adaptation and management plans extending their durability through time.

The information collected during the present state assessment and the future scenario analysis will finally be conveyed into a set of adaptation and management plans for the pilot sites. The plans will be set up by means of participatory processes based on common protocols, that will be defined and fine-tuned in order to be applicable within a heterogeneous community of stakeholders, scientists, policy makers, and technical/administrative operators. Besides the direct outcomes in terms of local benefits from an optimised decision making paradigm, one of the main achievements of this activity is a methodological approach enabling the identification of a set of criteria guiding the formulation and comparison of adaptation options in different geographical and socio-economical frameworks.

The overarching project objective is to consolidate the cooperation between coastal operators and scientific institutions on the ground of common data, tools and protocols aimed at better understanding climate vulnerability and raising the capacity of adaptation to climate change in the Adriatic coast, and up to the Mediterranean scale. At the same time, CHANGE WE CARE will improve the capability of local and regional authorities to overcome administrative weaknesses by enhancing the cooperation and by identifying commitments and responsibilities through the adaptation plans.

CHANGE WE CARE contributes to implement EUSAIR Action Plan and policy instruments and relevant initiatives at different scales, such as the Mediterranean Strategy for Sustainable Development (MSSD), BLUEMED Initiative on Blue Growth in the Mediterranean, Bologna Charter Joint Action Plan, ICZM Protocol of Barcelona Convention.

Anthropic impact conditioning pocket beach evolution of Torre Guaceto *(*Carovigno, Brindisi*)*

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Apulia sandy coastal mobile systems are strictly connected to two balance types, energetic and mass balances, which determine geomorphological and sedimentological features, useful to evaluate the current dynamic of a beach in combination with anthropic vectors which have acted in recent years.
Energetic balance is due to waves, flow and tide regime in long, medium, short term, while marine processes in combination with terrestrial and biological processes define the mass balance of a coastal system (Mastronuzzi et al., 2007).
In the mass balance, the human activity play an important role, contributing to input and output of coast sediment, as the tourist, urban, industrial activities can have a relapse on the coastal mobile system (Piscitelli et al., 2018).
In this work, a detailed study has been conducted on Torre Guaceto pocket beach, to highlight the influence due to some anthropic impacts. The latter is due to urban-industrial and touristic activities which are able to remove important amount of sediment (Dipanjan et al., 2014; Swagata et al., 2013; Zanchini et al., 2016). and/or decrease the amount of sands available for the coastal sedimentary system (Moretti et al., 2016; van Loon et al., 2017).
Torre Guaceto pocket beach (Carovigno, Brindisi, Southern Italy) shows a significant case of study where different processes influence coast evolution in combination with anthropic impact, so the knowledge of these processes is needed to understand the future behavior of this coastal system in the optic of Integrated Coastal Zone Management (ICZM).

Torre Guaceto pocket beach is located North of Brindisi city, inside of *Area Marina Protetta (AMP)-Riserva Naturale dello Stato di Torre Guaceto*, in Punta Penna Grossa locality.
In this area, different lithological units are presents, whose deposition is connected to past sea level changes and tectonic factors during Middle-Late Pleistocene (Mastronuzzi et al., 2011).
Tyrrhenian dunes (MIS 5) disconformably overlay the Calcarenite di Gravina Fm (Late Pliocene - early Pleistocene) and Middle Pleistocene marine terraced deposits.
Along the coast stretch between Torre Guaceto and Punta Penna, in the Last Glacial Time, sea level fall determined calcarenite bodies incisions, right in correspondence of current hydrographic network. Next, Holocene marine ingression and inter-strata dissolution caused a subsequent modeling producing a series of sub-circular inlets with narrow pocket beaches.
Here, a polyphasic dune system, with maximum elevation of 12 meters, was recognized and has been ascribed to two generation of Holocenic deposits (Mastronuzzi & Sansò, 2002; Mastronuzzi et al., 2017), the first with an age of 6000 B.P. and the second with an age of 2500 B.P.
Processes acting on Torre Guaceto pocket beach are due mainly to meteo-marine components, sedimentary masses movements, anthropic impacts, that have been studied through:

- Terrestrial Laser Scanner (TLS) survey, to obtain high resolution spatial data of the pocket beach;
- aerial photographs and satellite images interpretation, to estimate the shoreline rate changes and coastal system displacement;
- sedimentological analysis of backshore, foreshore and nearshore zones to characterize the granulometry and composition of sediments;
- sampling of sediment transported by anthropic vectors, to estimate quantitatively the amount of removed sand.

TLS survey highlighted the sand volumes of the entire beach in different times through point clouds analysis, in particular during summer periods.

Point clouds analysis has been conducted taking into account the difference observed in different filtered profiles extracted in different months, otherwise the areal volumes of sand were obtained in different months with meshes creation.
Results of point clouds analysis show a general coastal retreatment during summer periods.
This behavior has been showed also by aerial photographs interpretation, in which shoreline rate changes was obtained, taking into account the uncertainty about the shoreline position due to weather conditions, instrumental accuracy, informatics errors during processing with DSAS tools-ArcGIS (Himmelstoss et al., 2018).

Historical aerial photographs, from 1955 to nowadays, show main changes on shoreline and dune system, with a net shoreline retreatment of 10 meters for the entire coast stretch (Cacciapaglia et al., 2006).
Particular focus was given to the sand quantity moved from dune system in combination with measures of Brindisi-Casale anemometric station, located 15 km south of Punta Penna Grossa, which show a good fit between progradation direction of recent dune body (last 40 years) and frequency wind distribution.
More in-depth analysis for short-term changes was obtained through high resolution satellite images in combination with recent aerial photographs, in order to observe coastal behavior from 2006 to nowadays related to anthropic attendance.
To discriminate the entity of anthropic vectors in combination with this coast retreatment behavior, a series of sedimentological analysis were conducted both on the sands of emerged and submerged sectors of the beach and on them removed by tourists.
Sedimentological analysis were made sampling in nearshore zone up to isobaths of 6 m, in intertidal zone, and in correspondence of dune scarp (1.5 meters above mean sea level).Sands removed by anthropic vectors were sampled through a shower specially built with a series of filters to collect sediment adhering to the tourists bodies, at the moment of their exit from the pocket beach.
Sedimentological analysis, between sediment removed by anthropic vectors and sampled sand on the pocket beach, show same granulometry and composition, moreover, estimation on monthly touristic visitations, recorded by *Consorzio di Gestione di Torre Guaceto*, allow to establish a removed sediment rate of 3 m^3/year.

Furthermore, a multidisciplinary study has been started comparing the bioclastic component of the sands and the main ecological features of the seagrass area (that furnishes most of the organism fragments) in the Torre Guaceto coastal area. The touristic impact on the seagrass health can induce a loss of about 15-30% in volume of sands.
Detailed studies, with multi-criteria surveys, allowed to estimate the amount of removed sediments by anthropic vectors together natural processes, which determine a sand volumes reduction in the Torre Guaceto pocket beach, and in the next years can cause a significant decrease of sedimentary balance with subsequent loss of available emerged surface, so, for this reason, need arises to refine the operating methods for the sustainable management of coastal mobile systems where there is an high tourists frequency.

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Wave current interaction over rough beds

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Introduction

In shallow coastal waters the near bottom flow is often generated by waves and slowly varying currents, the latter being produced by phenomena such as radiation stress, set-up, tides or other factors. The thin wave boundary layer at the bottom, driven by the oscillating wave orbital velocity, strongly affects coexisting currents (Grant & Madsen 1979). Indeed the high shear velocity within the wave bottom boundary layer generates strong turbulence and large bed shear stresses which impact on the current, leading to increased bottom resistance in the presence of combined flows (Lodahl et al., 1998). The combined wave-current flow thus plays a fundamental role on the sediment transport, mixing processes, diffusion, and other important coastal phenomena.

Several researchers contributed to the understanding of the physical mechanisms of wave-current interaction, by analysing the combined flow over smooth or rough beds both experimentally or numerically. Most of these studies are focused on the effects on the velocity profile that a wave added to a pre-existing current has on the current velocity profile, particularly within the wave bottom boundary layer (Simons et al. 1992, Huang & Mei, 2003, Yuan & Madsen, 2015). More specifically, the case of orthogonal wave plus current flow over smooth and rough beds was investigated, among others, by Arnskov et al. (1993), Musumeci et al. (2006), Faraci et al, (2008, 2018), Lim & Madsen (2016).

Most of the aforementioned orthogonal wave plus current works could not reproduce both current dominated and wave dominated regimes, due to physical model constraints, but generally focused on the first condition. Nevertheless in Nature both situations are relevant, and the wave dominated one is probably more frequent than the current dominated one.

In this perspective the possibility to reproduce in the same setup both current and wave dominated conditions could contribute to shed light onto the velocity distribution along the water column and the apparent bed roughness as well as on the structure of the bottom boundary layers. Hence the main goal of this work is to acquire a considerable dataset of orthogonal wave plus current tests in both wave and current dominated regimes, propagating over beds with different roughness.

Experimental set up

Experiments were carried out within the DHI Shallow Water Basin. This facility allows the propagation of combined waves and currents at angles ranging from 30 to 90. The tank is 35 m long and 25 m wide with an overall depth of 0.8 m. The wavemaker front is 18 m wide, and it is obtained by means of an array of 36 piston type wave paddles, 1.2 m high and 0.5 m wide each. Each paddle is controlled by an electric-servo motor through DHI Wave Synthesizer software, allowing the wave type (regular or random), the water depth, the wave characteristics and the test duration to be set up. In Figure 1 a picture of the shallow water tank is reported. The origin of the reference system is located in the upper left corner of the basin; the x-axis follows the current direction, while the y-axis is directed as the wave propagation direction. z-axis has the origin at the bottom and points upward.

The 3D wave generator is designed to operate at water depths D between 0.2 m and 0.8 m. A C-shaped gravel beach with a slope of 1/5.6, coupled with passive parabolic wave absorbers, provides energy absorption at the opposite end of the wave basin.

The shallow water basin is also equipped by a three-pump system able to supply a discharge of 1 m3=s. In order to get the desired current velocity, the inlet width was reduced from 25 to 12 m, and at the end of the inlet a series of panels were placed along the current direction to direct and straighten the flow.

Two different rough beds, namely a sand bed (SB) and a gravel bed (GB) were installed in the wave current interaction area of the basin, covering a surface of 5x7.5 m. They have been obtained by gluing sand (d_{50}=0.9-1.6 mm) or gravel (d_{50}=16-32 mm) on wood tiles, whose dimensions are 1.25 x 2.5 m each. The tiles were thus drilled on the concrete floor in order to be fixed.

A set of 24 resistive wave gauges, located in the central part of the basin where waves and currents interact with each other, allowed the free surface to be recovered.

Velocity profiles were acquired by means of several high resolution Acoustic Doppler Velocitimeters (Vectrino produced by Nortek As.). More in details, five Vectrino Single-Point (VS), four of them down-looking and one side-looking, and one Vectrino Profiler (VP) have been employed in the present experimental campaign. Four VS were placed in a square shape, whose side was equal to 0.12 m, while one VS occupied the centre of the square. The whole system was held by a trolley mounted on a bridge and vertically moved by means of a micrometer. The sampling volume of the VS probe is located 50 mm far from the transducer and its dimensions can be modified via the acquisition software in relation to the desired quality of the signal; the sampling rate is 200 Hz. The sampling volume of the VP probe extends from 40 mm down to 74 mm below the transducer, typically divided into 34 measuring cells with 1 mm resolution and sampling rate equal to 100 Hz. The position of VSs and VP was defined on the basis of a preliminary campaign focused on the definition of an area inside the basin where both waves and currents could maintain a steady state.

Figure 1: Experimental set up and instrumentation location.

Experimental results

Velocity profiles were acquired for current only (CO), wave only (WO) and wave plus current (WC) flows in the presence of both sand bed (SB) and gravel bed (GB) both in wave dominated and current dominated conditions. Her for sake of brevity only current dominated conditions are shown.

In Figure 2 a comparison between the spatially-averaged velocity profiles acquired in the current direction for a current only, a wave only and a wave plus current condition is shown. More in detail, in Figure 2a Run1 (CO), Run3 (WO), Run7 (WC) acquired in the SB case are plotted (d=0.4 m, H=0.12 m, T=2 s). While the wave only profile, as expected, shows only fluctuations around zero, the CO and WC profiles exhibit an increasing velocity from the bottom up to about 0.2-0.3z=d. Here only the mean profile is plotted while the variability observed among the different Vectrinos is depicted in terms of an errorbar. Such variability is maximum at the bottom and it almost disappears when moving away from the bed. Moreover CO and WC profiles are almost superimposed for all the investigated water depth. In Figure 2b Run32 (CO), Run36 (WO), Run34 (WC) acquired in the same flow condition (d=0.4 m, H=0.12 m, T=2 s) but on a gravel bed (GB) are presented. It can be observed that increasing the bed roughness leads to a strong deceleration close to the bed, which is compensated by an increase of the velocity in the upper part of the investigated water column, where wave plus current flow appears stronger than the correspondent current only test, as also observed by Lodahl et al. (1998) and Musumeci et al, (2006).

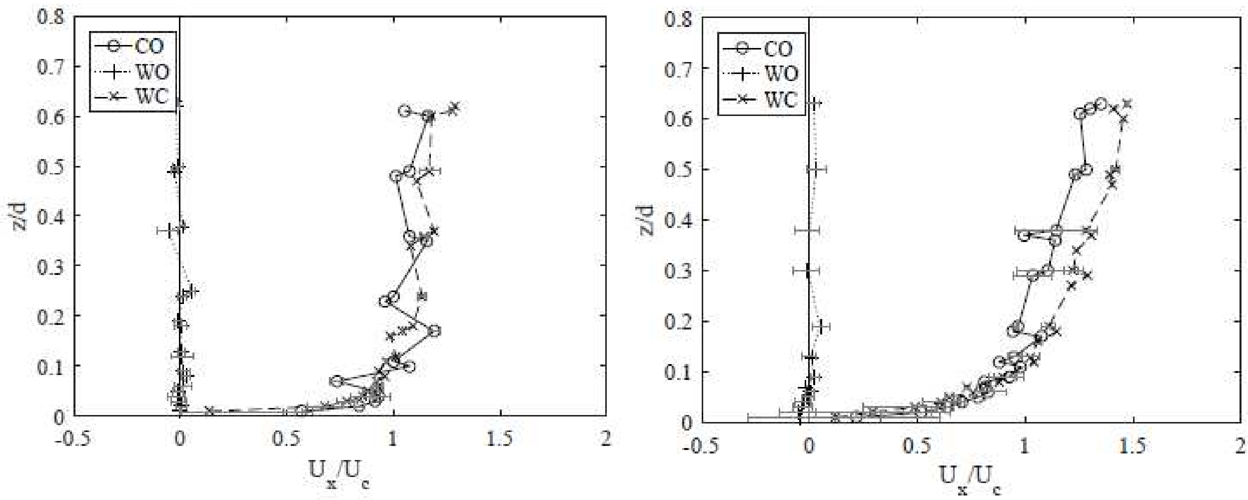

Figure 2: Velocity profiles along the x direction in the SB case Run1 (CO), Run3 (WO), Run7 (WC) d=0.4 m, H=0.12 m, T=2 s; in the GB case Run32 (CO), Run36 (WO), Run34 (WC) d=0.4 m, H=0.12 m, T=2 s

Conclusions

The present paper investigated some wave–current interaction features in the presence of beds characterized by different roughness. Experiments were carried out in the DHI Shallow Water Basin acquiring velocity profiles by means of several Vectrinos and surface waves by means of resistive wave gauges. Velocity profiles showed that bed roughness has a relevant effect on the combined flow. Indeed in the presence of a sandy bed, current only and wave plus current flows exhibit a similar behavior, while when a gravel bed is taken into account, the boundary layer stretches almost to the double of the sandy bed case; moreover, in the WC case, the combined flow shows a higher velocity with respect to the current only case as a result of the near bed deceleration (Lodahl et al., 1998, Musumeci et al, 2006).

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Morphodynamic evolution of the Ombrone River delta through mathematical reconstruction of beach ridges

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Introduction

Deltas are important dynamics environments constantly reshaped and reformed (Brown and Nicholls, 2015). Morphologies are linked to river input, marine weather conditions and tides (Galloway, 1975). According to the Galloway delta classification, the sub-aerial cuspate morphology of the wave-dominated delta plain, is associated to the variation in waves and longshore transport conditions.

Beach ridges, typical morphologies of prograding coastline, are associated to ancient shorelines (Bellotti, 1999; Otvos, 2000) and often related to the sediment input variation (Anthony, 1995).

Changes on fluvial input and waves conditions are reflected in an alternation of progradation and erosion phases. Progradation periods bring a higher sedimentation on the updrift lobe of the delta apex and the rotation of the river mouth updrift, towards the dominant wave front direction. The downdrift side is characterized by discontinuous shoreline morphologies with the presence of some wetlands. A reduced fluvial input, on the contrary, determines a downdrift rotation of the apex (Komar, 1973; Nienhuis et al., 2016a). Numerical models of river mouth erosion and wave reworking of abandoned deltas have been proposed by Nienhuis et al., 2013. The delta of the Ombrone River presents similar characteristics and behavior: the delta apex rotates to South-West direction during more expansive periods (Pranzini, 2001).

Different evolution phases induce a change in the geometry of beach ridges pattern that can be used for understanding past delta dynamics (Pranzini, 2007).

The aim of this work is the reconstruction of the beach ridges morphologies, often deleted by the river delta dynamic and human activities, through mathematical functions in order to better understand the Ombrone River delta evolution and to obtain a complete beach ridges pattern map.

Study area

The study area is the Ombrone River delta, located in the South of Tuscany between Castiglione della Pescaia and the Uccellina Mountain. The delta plain is crossed on both side of the river by beach ridges (Fig. 1). The dominant wave front direction is from the third quadrant (Aminti and Pranzini, 1990) and we assumed the wave climate constant over time (Liang et al., 2015, Meini et al., 1979). The regional longshore transport is directed from South to North (Aiello et al., 1976, Aminti P., 1983), subsidence is considered to be about 3 mm/year (Salvioni, 1957) and sea level was about 1 meter lower during the roman period (Antonioli and Silenzi, 2007).

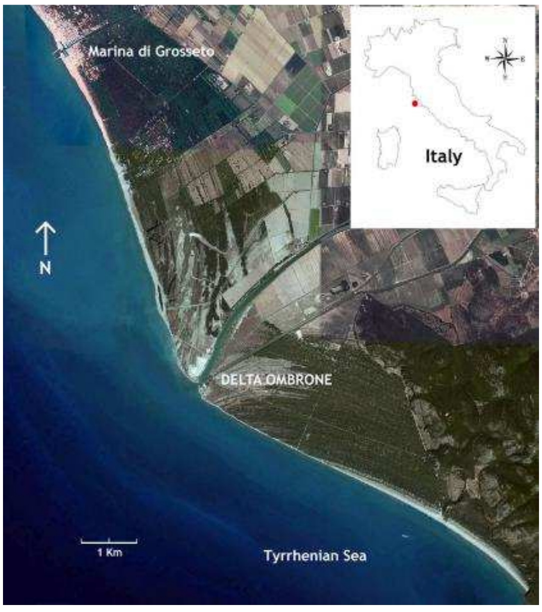

Fig. 1: Ombrone River delta

Material and methods

Using remote sensing data as Lidar (Light Detection and Ranging), aerial and satellite images, historical maps, regional cartography and topographic surveys we could reconstruct a detailed beach ridges map present in the delta basin. All the data were elaborated using ENVI 4.5 and ArcGIS 9.3 software. Georeferenced historical maps and a cross shore profiles matching, allowed us to associate beach ridges on the two delta lobes.

One of the main problems that can be encountered in studying the evolutionary dynamics of geomorphological and coastal phenomena is the loss of original information due to natural and anthropic transformations over time or for the few historical data available. In our study area, beach ridges related to expansive phases have been erased by subsequent erosive periods, those related to erosive periods are instead erased mainly near to the river by coastal dynamics or human activity.

A reconstruction of deleted beach ridges segments was needful for understanding the Ombrone River delta dynamic and to obtain a complete pattern map. For their reconstruction a mathematical functions were applied. This was developed from the observation of the beach ridges geometry and how their planar trends remind some mathematical functions.

Using a curve fitting software, different regression models have been applied to interpolate 16 beach ridges curves from the 15th century until 1850. The work focused on finding the mathematical functions characterized by the lowest number of variables, in order to make easier the calculation of the coefficients and the analysis of their trend and to have a good index of significance.

Initially a logarithmic and time dependent variable function was tested, trying to be able to reconstruct the missing beach ridges just by entering a desired year. More complex functions have been also tested not depending on the time. We found out two distinct families of functions, respectively Weibull (Eq.1) and MMF (Eq.2) with acceptable values of standard error and correlation coefficient comparing to the position beach ridges trends.

Weibull: $$y = a - be^{-cx^{d}} \qquad \text{Eq.1}$$

MMF: $$y = \frac{ab + cx^{d}}{b + x^{d}} \qquad \text{Eq.2}$$

Results

Results showed as the logarithmic function could less well estimate the missing beach ridges section near the river mouth in comparison to the Weibull and MMF equations. The first one approximates rectilinear beach ridges, typical of the river mouth erosion; the second function is related to the curved beach ridge morphologies, according to the accretion of the river mouth. Reconstruct beach ridges belonging to main evolution phases of the Ombrone River delta, deleted near the river or truncated by a subsequent erosive events are reported in Fig. 2. In cyan we represented beach ridges related to erosion of the river mouth and in red those related to the cuspate progradation. In blue and purple the reconstructed morphologies with mathematical functions. Once mapped and coupled all the beach ridges and reconstructed those deleted by erosion through mathematical functions, accretion or erosion areas belonging to the main historical phases have been computed in ArcGis 9.3. The results are reported in Fig. 3 with also related time periods.

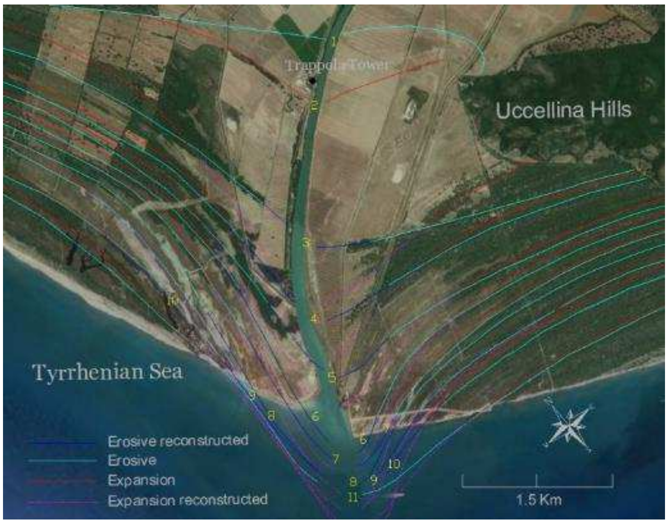

Fig. 2: Beach ridges reconstruction for main historical phases

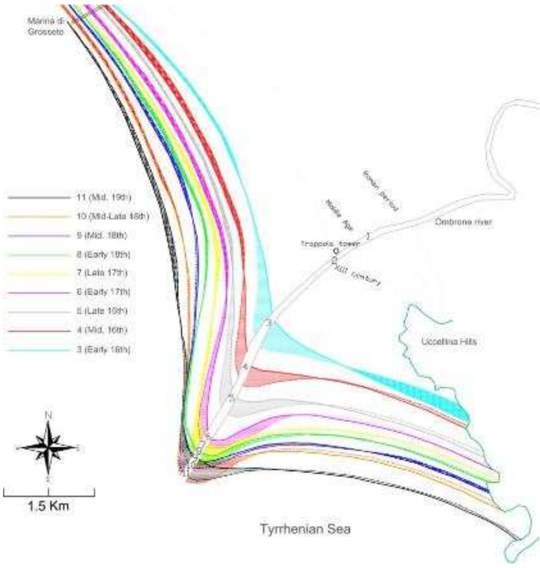

Fig. 3: Ombrone river delta's main evolution areas (16-19th century).

In order to better understand the evolution of the Ombrone river delta we calculate the areas related to the propagation and erosion phases. Total area computed is about 10 million m^2 for the downdrift wing and 7.5 million m^2 for updrift side. The delta areas variation for the main evolution phases is reported on Fig. 3. For each erosive phase the immediately previous progradation period has been selected. Area Calculation was considered until Marina di Grosseto to the north and Uccellina Hills at south and reported in Fig. 4.

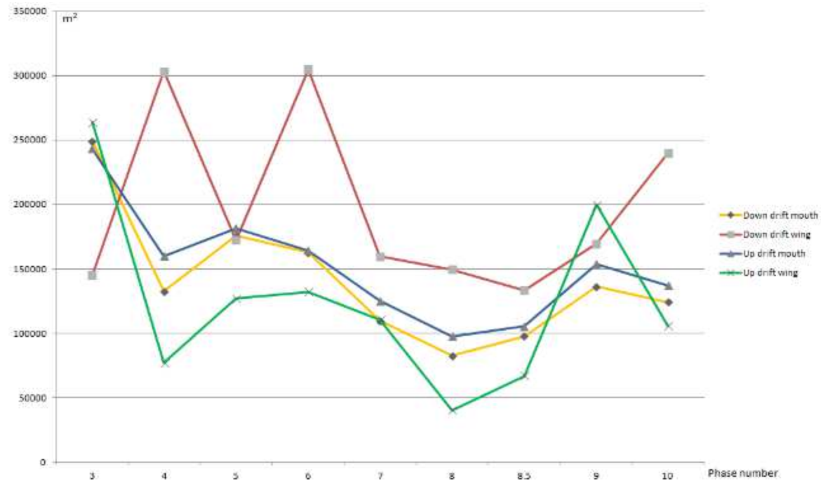

Fig. 4: Area variation diagram during different evolution phases

Discussion and conclusion

We have seen as morphodynamic evolution of river deltas is characterized by an alternation of progradation and erosion phases. During high river input the accretion of the delta is mainly concentrated on the river mouth while the erosion of the cuspate produces accumulation on the wings. Material transported by cuspate erosion nourishes more the downdrift wing (north); especially over time. It can be noticed a greater updrift sediment deposition during cuspate expansion except for phase 3, where the river mouth was more north oriented because of the less river input. During the high river input, like the XIX century, we have a bidirectional longshore transport on the apex and material will be transported updrift (phase 9). In the ancient time when the delta apex was not symmetrical and not oriented towards the dominant waves, we have seen the material have been deposited on the north wing, downdrift. This evidence makes it suppose a higher influence of erosive events on the delta dynamic evolution.

Finally a map of all beach ridges, mathematically reconstructed, matched and dated, of the whole delta plan has been realized. This information permitted also a detailed analysis of the behavior of the two lobes of the delta at the same time interval that is very important for the understanding of the different evolutionary phases. The use of these high detailed information allowed a redefinition of the erosion and accretion historical phases of the Ombrone River delta and a new interpretation of the evolution also using the beach ridge pattern conceptual model.

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Erosional processes at the toe of a flood defense structure during sea storm sequences

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Abstract

The erosional processes induced by sequence of sea storms are here investigated in the case of an engineered beach. The aim is to evaluate the influence of the morphological changes induced by storm sequences on the flood defense performances. Results from an experimental campaign carried out at large scale are presented. The experimental layout adopted consisted of a 10/1 battered seawall and a natural sandy foreshore with an initial 1:15 slope. Three storm sequences were simulated, each consisting of three individual storms. Two triangular storm profiles made up by six sea states were considered, the first one with a lower level of energy and the second one with a higher one; additionally, mean water level changes were considered. Results confirm that the higher erosional processes are observed for storm characterized by high level of energy. The temporal sequence of the storm events plays a role in accelerating or slowing down erosional processes along the beach and at the toe of the wall.

Introduction

During sea storm events the natural beach evolution, thanks to the well-known morphodynamics processes as the bar formation, contributes to the natural defense of the coast. This capability diminishes if no recovery time is allowed. The impacts of storm groups in close succession have been studied since 1998 (Lee et al.,1998). Recently, Karunarathna et al. (2014) showed that clusters of small storms occurring at close intervals can produce more damage than isolated large single events. Engineered beaches, with a flood defense structure at the back of the natural beach, are very common. During extreme events, the natural and the engineered components of these systems interact with each other, by affecting the morphodynamics of the foreshore. Notwithstanding the popularity of such type of systems, the effects of storm sequences on them has never been investigated.

The present work illustrates results obtained by the ICODEP (Impact of Changes in the fOreshore on coastal DEfence Performance) project, a large-scale experimental investigation aimed at analyzing the influence of bed mobility at the toe of the flood defense structure on the performance of the flood defense structure. Here the morphological evolution of an engineered sandy beach with a sloped seawall is analyzed under energetically different sequences of storms. Attention here is focused on high spatial and temporal resolution measurements obtained by means of a 2D laser scanner.

Experimental apparatus

The experimental campaign has been carried out at the Großer Wellenkanal (GWK) of the Leibniz University of Hannover and the Technical University of Braunschweig (see Figure 1). Large-scale tests have been performed adopting a wave channel 300m long, 5m wide, 7m deep (Figure 1a). The sandy beach has a slope of 1:15 and it is characterized by sediments of d_{50}=0.3mm. The sea wall located at the end of the beach is 10:1 sloped (Figure 1b).

Different instruments have been adopted for acquiring data on the characteristics of wave motion and of morphological changes. A total number of 18 acoustic and resistive wave gauges have been installed along the channel length to measure free surface elevation. Four Acoustic Doppler Velocimeters were adopted to acquire data on the velocity field at different beach sections. These have been co-located with Acoustic Backscatter Sensors for knowing the concentration of the suspended sediments. The morphology of the beach profiles was recovered by means of a 2D- Laser scanner and a 3D-laser scanner. During the ICODEP project, also data on oovertopping volumes and wave impacts on the wall have been acquired by a gravimetric wave overtopping tank, a force plate and an array of pressure sensors on the wall.

a) b)

Figure 1 Engineered beach at the Großer Wellenkanal (GWK) of the Leibniz University of Hannover and the Technical University of Braunschweig: a) wave flume and initial 1:15 sloping beach profile; b) model of the seawall 10:1 sloped.

Experiments

Different sequences of storms have been investigated (see Figure 2). They were obtained by combining two storms profiles: S1 and S2. The first one is characterized by lower energy, while S2 is more energetic, with the smallest wave height H_s in S2 being the same as the highest wave in S1. Each storm profile is composed by six sea states (T1, T2, …, T6), lasting about 30 minutes each. The peak of the storm is reached during trunk T3 for all storms. In order to take into account the effect of the tide and storm surge, the mean water level h_0 is larger during the third and fourth trunks of each storm. The following sequences of storms have been considered: C1 (S2-S2-S2); C2 (S2-S1-S2); C3 (S1-S2-S1). At the beginning of each storm cluster, the beach starts from an initially planar 1:15 sloping beach, then it evolves because of the wave attack, of the changing water level and of the wave-sediment-wall interaction.

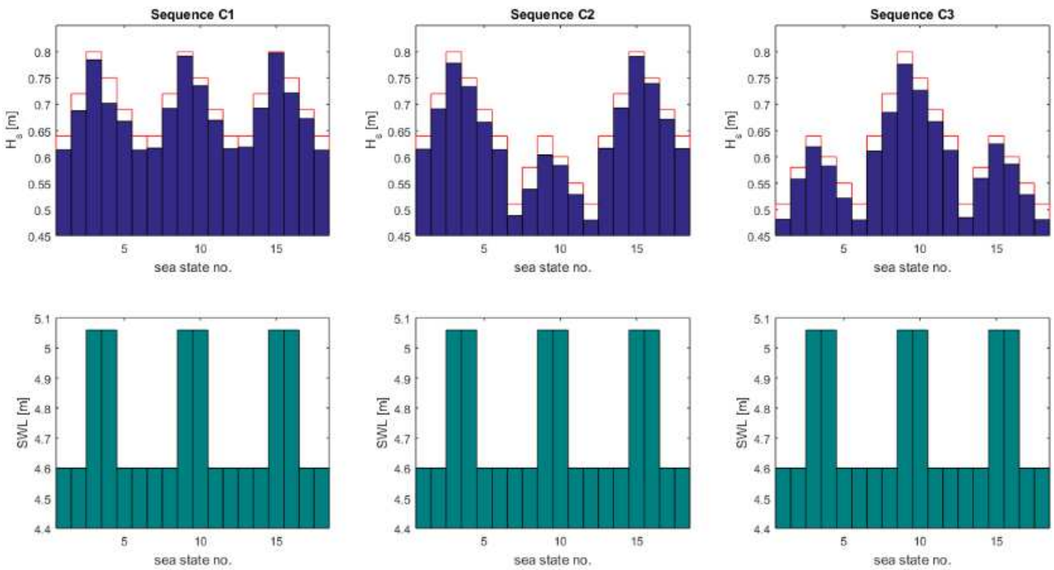

Figure 2 Sequences of triangular storms considered by combining a low energy storm (S1) and a higher energy storm (S2). Blue: measured incident significant wave high H_s; red: target H_s. Each storm profile is made up by six different sea states (T1, T2, …, T6). The influence of changing water level (e.g. due to surges, tides, etc.) is considered. The peak of the storm corresponds to high water conditions.

Results

The morphodynamic processes acting on engineered beaches during storm sequences are investigated here, focusing on the beach portion located at the toe of the flood defense structure. The analyses are carried out using the data acquired by a 2D- Laser scanner, which was running continuously during the experiments.

During the realization of a single storm both accretion and erosion processes are recognized. Typical accretive conditions are observed during the first two sea states T1 and T2. Erosion with the scour formation at the toe are observed for the third and fourth sea states, which are partially recovered during the last two sea states.

Storms characterized by different level of energy induce difference in the erosional processes occurring at the toe. Figure 3 reports the comparison between the beach evolution observed during the first sea state of the C1 sequence and the C3 sequence respectively. In case of more energetic sea state (C1) we observed that the beach profiles create a much larger sand deposition in front of the wall, with a relatively small scour (Figure 3a from yellow o blue), when compared with the results of the low energetic condition (C3, Figure 3b). In both hydrodynamic conditions, the sediment transport processes observed is locally accretive with a beach profile rotation around the mean shoreline position. Although the beach accretion observed at the toe of the wall is realized here by a mechanism of beach profile rotation, in other sea states erosional processes occur because of beach profile solid vertical translation.

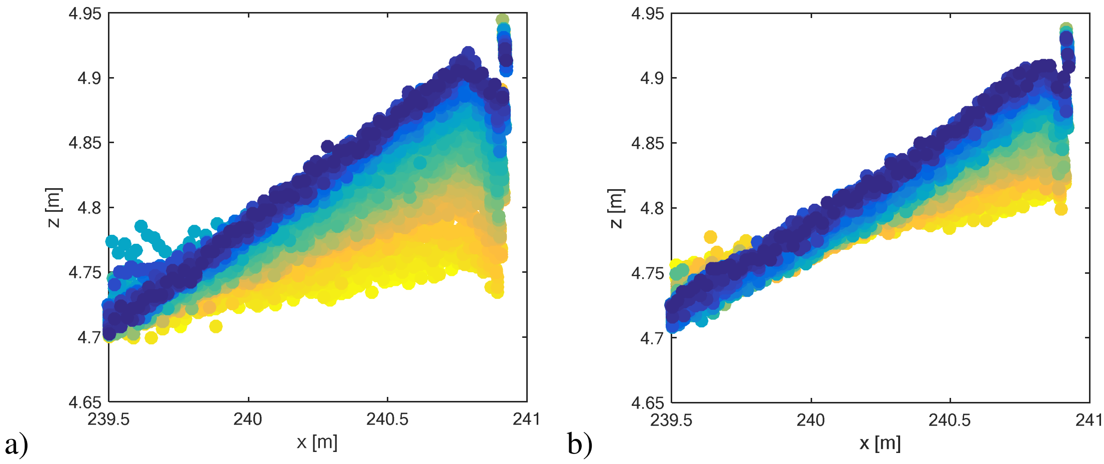

Figure 3 Beach evolution (time increases from yellow to blue) acquired during the first sea state realization respectively for the a) storm sequence C1; b) storm sequence C3.

Analysis on the influence of the temporal sequence occurrence have been also performed. In particular, observing the beach profile evolution at the end of the second storm of the C2 sequence and C3 sequence, when the beach was attacked in both cases by a low energetic storm and a high energetic storm, differences in the beach profiles are observed in terms of the erosion at the toe of the wall (see Figure 4).

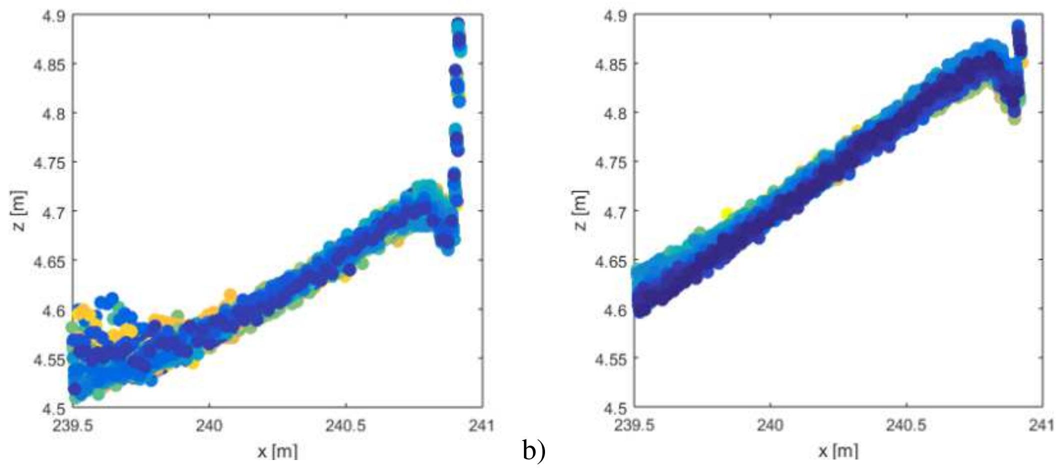

Figure 4 Beach evolution (time increases from yellow to blue) acquired during the second sea state realization respectively for the a) storm sequence C2; b) storm sequence C3

Higher erosion is observed when the storm with lower energetic content is preceded by a storm with higher energetic content (C2 storm sequence). Although the beach slope observed at the toe is the same for the case analyzed (C2 and C3). This result confirms the importance of the temporal occurrence in the morphological processes.

Conclusions

Results from a large scale experimental campaign ICODEP on the Impact of Changes in the fOreshore on coastal DEfence Performance are here presented focusing on the morphological features observed at the toe of the structure. The influence on the erosional process observed for single storm and for storm sequences is analyzed. In case of a high energetic storm the erosional processes (accretion/erosion) are magnified when compared to the observations acquired for a low energetic storm realization. Moreover, beach evolution is also influenced by the temporal sequence of the storm's occurrence. Indeed, when we compare beach profiles acquired after the wave attack of two storm sequences, each one characterized by the occurrence of two equivalent storms (low and high energetic one) but reversed in time, we obtain different beach profiles pointing out the importance of actual temporal sequences.

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Statistical correlation and GIS analysis to evaluate shoreline evolution

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Wind, waves, tides, sediment supply, changes in relative sea level and human activities strongly affect shorelines, which constantly move in response to these processes, over a variety of time scales. In addition, during the 20th century, increasing populations, urbanization and development activities have started altering littoral processes and thus the provisions of these services.

As consequences, shoreline evolution, characterized by erosion and deposition areas, have effects on socio-economic activities and ecosystems, therefore their evolving and understanding represents a challenge to coastal communities, coastal infrastructures and adjacent estuarine environments. Thus, the implementation of sound coastal zone management strategies needs reliable information on erosion and/or deposition processes (Cutter et al., 2008; Torresan et al., 2012; De Serio and Mossa, 2014; 2016; Samaras et al., 2016; De Padova et al., 2017; Armenio et al., 2017a, Armenio et al., 2018).

Moreover, coastal environments are subject to continual adjustments towards a dynamic equilibrium, differently responding to fluvial/sea dominated events. To evaluate changes in coastal regions and recognize some key physical processes over different historical timescales (decade to century), data of shoreline geometry and position are basic indicators. A quantitative analysis of data of shoreline evolution at different timescales and with a fine spatial resolution is fundamental in establishing the processes driving erosion and accretion (De Serio at al., 2018; Elfrink 1998; Katz et al, 2013; Oyedotun, 2014).

With the passing years different methods have been used to estimates the distance of the shoreline movement rated by the time elapsed between the oldest and the most recent shoreline many of them have been based on GIS tools. Moreover, statistical procedures have been also used to evaluate the linear regression rate-of-change by fitting a least squares regression line to all shoreline points for a transect (Dolan et al., 1977), thus deducing the rate as the slope of the line. An iterative linear regression fitting all possible combinations of shoreline points, leaving out one point in each iteration, has also been implemented, i.e. the jackknife (JK) method (Dolan et al., 1991).

Questions raise considering coastal embayments featured by a parabolic curve, which are representative of more than 50% of the world’s coastlines. They are very dynamic environments where the shoreline position can fluctuate significantly due to processes such as beach rotation (Armenio et al., 2017b; Short et al., 2004; Blossier et al., 2015). This can be defined as the landward or seaward movement at one end of the beach accompanied by the reverse pattern at the other end (Bryan et al., 2013) and is often a consequence of maritime constructions (i.e. dikes, breakwaters) and variations of river sediments supply on flanking beaches. As well, in shorter-term, also changes in wave direction could contribute to this marked shoreline readjustment.

The present work shows a feasibility way to identify critical coastal areas and the evolutionary trend. The methodology proposed has been based on the joint application of GIS tools and statistical correlation. The coastline morphology has been analysed through interannual aerial photographs and plane-bathymetric surveys. Subsequently, rates of shoreline changes have been calculated by using a specific GIS tool and statistical analysis has been applied to detect correlation among the historical shoreline positions. The first step of the approach proposed has been the analysis of field information and shoreline data to examine the past behavior of the coastline, the impacts of human activities on shoreline movement and rates of change. Afterward, GIS tools have been applied for the quantification of shoreline rate of change for interannual periods. Statistical analysis, i.e. the regression model and the Person’s correlation matrix, have been used to investigate possible relationships of historical shoreline profiles.

The aim of our work has been providing a feasible, general and replicable chain approach, which could help to thoroughly understand the dynamics of a coastal system, identifying typical and recurrent erosion/accretion processes, and help in predicting possible future trends, useful for planning coastal activities.

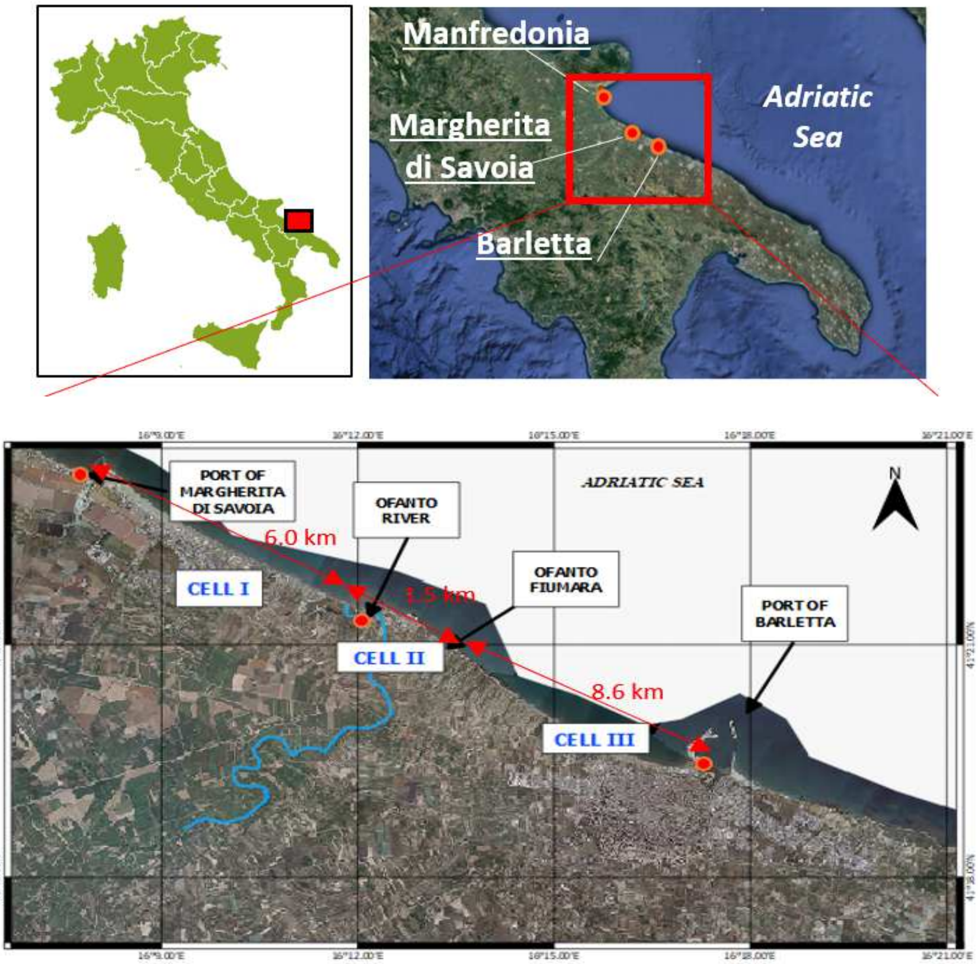

Figure 1: Study area with notation of Cell I, Cell II and Cell III.

The proposed approach has been applied to a target area located in southern Italy along the Adriatic Sea, characterized by a coastline 18 km long. The study area extends from Margherita di Savoia town to Barletta town (Figure 1) and it is characterized a low sandy beach with dunes, wetlands and salt marshes. At approximately 2 km off the coast the depth is around 13 m.

The sandy coast has been originated from the sediments supplied by several rivers, flowing into the gulf. Especially, one of the most significant contribution to solid transport was due to Ofanto river, whose length and flow rate are respectively 134 km and 15 m3/s (annual average), has significantly influenced the coastline evolution.

It is worth noting that, in the last two centuries, both the rivers and the coastal area have experienced remarkable modification mainly due to human activity, with resultant alternating erosion and deposition processes. In the early 1800's during some remediation works, river sediments were used to bury marshes and in canalization works, thus provoking a reduction in sediment supply from land and a widespread coastal erosion. In the mid-1900's, several reservoirs and crossbars were constructed on the Ofanto river and its tributaries, to assure water supply for irrigation, industrial and drinkable uses. Since 1960, the intense urbanization of the coastal zone has provoked critical local issues, furtherly contributing to erosion phenomena.

Furthermore, the most perturbing cause in the coastal dynamics between the Ofanto's mouth and Manfredonia town (Figure 1) was the construction of the port of Margherita di Savoia, started in 1952 and completed forty years later. The port structure has altered the beach equilibrium of the adjacent coast leading over the years to a change in the coastal morphology from linear to curve shape beach profile (Damiani et al., 2003).

For the aim of the present work, the coastline in the study area has been divided into three parts with relatively homogeneous geomorphological change patterns, respectively named Cell I, Cell II and Cell III (Figure 2). They all have a curvy geometry. Cell I and Cell III are two concave beaches (i.e. curved towards the sea) and are separated by Cell II, which is convex (i.e. curved towards the inland). Cell I is delimited by the Margherita di Savoia's port northerly and by the Ofanto river's mouth southerly. It has a length of about 6.0 km. Cell II extends from the Ofanto river's mouth up to a residential area called Fiumara, for a total length of about 1.5 km (Figure 1). Its convex coastline is characterized by the alternation of sandy and rocky beaches, with breakwaters and rip-rap seawalls also placed to protect the beach. Cell III connects the Fiumara site with the Barletta's port, with a total length of about 8.6 km of sandy beaches.

To quantify the coastal evolution in the investigated period, the shoreline variation has been statistically analyzed using the Digital Shoreline Analysis System (DSAS) extension in (ESRI) ArcGIS © software. The DSAS has firstly been implemented to map the shoreline positions occurred during the investigated period, based on the available spatial data (e.g. maps, aerial photographs). Secondly, several transects orthogonal to the coastal orientation have been considered. The intersection between each transect with the historical shorelines has been marked and the distance between the oldest and the most recent shoreline has been computed. The distance migration of the shoreline, either seaward or landward, has been estimated for the period from 1992 to 2013.

Overlaying the historical shorelines of years 1992, 1997, 2005, 2008, 2011 and 2013, the first comparative spatial analysis has been executed, to analyze and map areas of accretion and erosion in all the investigated Cells. A shoreline accretion has been evident in Cell I and Cell III which are in the proximity of the Port of Margherita di Savoia and the Port of Barletta, respectively. On the contrary, in Cell II (area of Ofanto river) significant erosion has occurred.

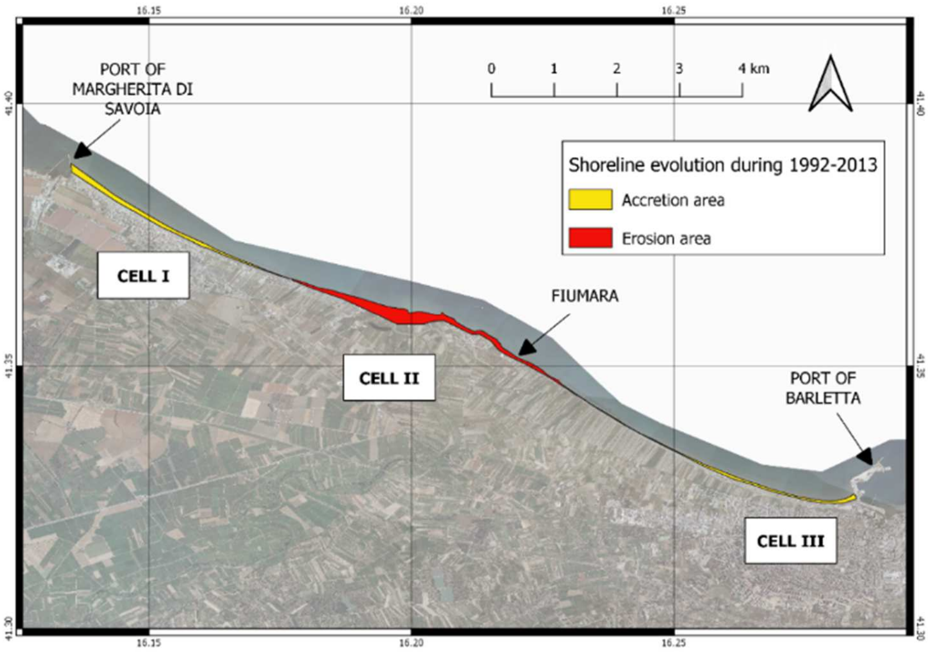

Figure 2: Accumulation and retreat areas in Cell I, Cell II and Cell III during the overall observation period (1992-2013).

In the method adopted some helpful information have been inferred by plotting in a joint graph the temporal shoreline changes occurred within each Cell with reference to the southern, central and northern sectors, respectively. Particularly, referring to the 1992-2013 curve, a consistent correlation emerges between southern and northern evolution for each cell. A high correlation between the southern shoreline retreat and the northern shoreline advance is evident in Cell I and is fitted by the 5 linear regression model $y=-80.427x+170.77$ with a correlation coefficient $R^2=0.93$. In Cell II, the large erosion is proved by the linear regression model $y=68.013x-250.02$ with $R^2=0.90$. Also in Cell III a linear regression model $y=19.869x-37.637$ with $R^2=0.93$ expresses the shoreline behavior, in this case with opposite slope in comparison to the linear regression model of Cell I, thus indicating retreat in the northern part and advance in the southern one.

The further step has been aimed to investigate detailly the mutual influence of each sector on the adjacent one. Correlations between the northern-central, southern-central and southern-northern sectors are evaluated by calculate the regression equation with the corresponding R^2.

To investigate thoroughly these linear correlations, the Pearson correlation coefficient, r, has been computed. Specifically, it provides a measure of the linear association between two continuous variables, in this case assumed to be some appropriate profiles, obtained in the following way. The 244 transects of Cell I have been grouped in 15 profiles (P1 -P15 from North to South). Similarly, the 45 transects of Cell II have been grouped in 9 profiles (P1-P9 from North to South) and the 289 transects of Cell III in 12 profiles (named P1-P12 from North to South). Each of these profiles represents the time-average of the 5 shoreline changes observed in the period 1992-2013 along few consecutives transects. As an example, the profile P1 is the time-average of the shoreline changes observed along transects T1 to T16, the profile P2 refers to transects T17 to T32 and so on. For each Cell, using the year 1992 as a proxy shoreline, the Pearson's correlation matrix has been calculated to attempt a best fit and compare the temporal variations along the profiles.

The temporal analysis of the shoreline variation by means of the GIS application has clearly shown the location of accretion and erosion areas. It has proved that in Cell I and Cell III the coastline has evolved, keeping its concave shape but rotating. A clockwise rotation has been observed in Cell I, with the formation of a northern area of sediments deposit and a southern erosion area. In Cell III an anticlockwise rotation of the coastline has produced an advance of the beach in the southern region and a retreat in the northern one. Cell II has been characterized by a progressive erosion so that the convex shape beach profile has reduced over the years. These results have also been proved by the application of the linear regression model in each Cell and the computation of the Pearson's matrix, which have allowed to thoroughly investigate on correlations between northern, central and southern shoreline position.

The methodology implemented has demonstrated that the statistical analysis of data remains an accurate method to characterize shoreline changes, even if it disregards potential changes due to engineering activities or major climate change.

The proposed procedure has shown that this joint approach in the analysis of the coastline evolution is successful, providing complete information, both qualitative and quantitative, to stakeholders and identifying areas of erosion and deposition.

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Urban expansion depletes cultural ecosystem services. An insight into the Mediterranean coastline

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Introduction

Coastal dunes comprise about three-quarters of the world's shorelines (Bascom 1980) and are crucial for human health, guaranteeing fundamental services (MA 2005) with significant socio-economic impacts (Everard et al. 2010; Jones et al. 2011; MA 2005). Coastal dune systems, being preferred environments to relax and unwind and representing a source of mental well-being, have a vital role for recreation and tourism (Everard et al., 2010).
At the same time coastal dunes are among the most fragile and threatened ecosystems worldwide (Schlacher et al., 2007). In Europe urban expansion, agricultural and reforestation spread and industrial and harbor sprawl along the coasts have developed with a striking rate during the 20th century (Couch et al., 2007; Malavasi et al., 2013). In Italy, almost 85% of natural coastal habitats have suffered a drastic reduction in both extent and ecological quality, mainly due to urban sprawl (Falcucci et al., 2007; Genovesi et al., 2014).
In the Mediterranean sandy coasts, urban expansion mainly occurs to support sea-side tourism, altering drastically the integrity of dune landscapes (Drius et al., 2013); however, further research efforts are needed to investigate how the supply capacity of recreational value is affected by urban expansion.
The present work sets out to quantify how land conversion into urban areas occurring in the last 20 years has affected the recreational value supply of Mediterranean coastal dune ecosystems. First, on the basis of detailed multi-temporal land cover maps, we quantified the conversion of natural dune habitats into artificial areas over time, by means of transition matrices. Then, using empirical data, we quantified the recreational value provided by the main dune habitat types. Last, we measured how the natural dune habitats' loss reduced the related supply capacity of recreational value.

Materials and methods

Study area

The study was carried out on a representative sector of the Adriatic coast in Central Italy (Molise Region), characterized by a narrow strip of recent dunes (Holocene) hosting a typical vegetation zonation, that ranges from pioneer annual plant communities on the upper beach to woody communities on the landward fixed dunes (Acosta et al 2003). During the last 50 years, more than 50% of this area changed in terms of land use, mainly because of the expansion of artificial areas and agricultural lands (Malavasi et al., 2013).

Multi-temporal land cover maps

We used two fine-scale (1:5000) land cover maps for the years 1986 and 2006, derived from panchromatic digital aerial ortho-photographs with a 1 m resolution (see for details Malavasi et al., 2013). The legend conforms to Corine Land Cover (CLC) expanded to a fourth level of detail for natural and semi-natural areas (Acosta et al., 2005). Ten land cover typologies were identified and mapped. Particular attention was given to natural dune cover types which, according to Acosta et al. (2005), were mapped in three different categories, which enclose 6 EU Habitats *sensu* Habitats Directive (Biondi et al. 2009; Stanisci et al. 2014): Beach with Pioneer annual Vegetation (**BPV**: including annual vegetation growing close to the drift line and embryonic dunes EC 2110); Dunes with Herbaceous Vegetation (**DHV**: including partially vegetated EC2230 and densely vegetated dunes EC2120) and Dunes with Woody Vegetation (**DWV**: corresponding to the woody vegetation growing on fixed dunes EC2250*, EC2260 and EC2270*)

Recreational value

To assess the recreational value we considered people's perception towards natural dune ecosystems (Everard et al 2010; Palombo et al 2013) assessed through 591 questionnaires of beach users. Questionnaires were supplied to the tourists and residents during summer seasons 2014, 2015 and 2017. People interviewed once were not interviewed again. Interviewees' profiles were characterized in terms of gender, age, education level, place of residence and profession, whereas a specific question was designed to draw out users' perception towards the coastal natural features. Specifically, we asked "How important do you consider the following natural features: sandy beach, sand dune vegetation, and pine forest?" where natural features correspond to *BPV*, *DHV* and DWV respectively. The answers were structured into five categorical alternatives: "not important (*NI*)", "scarcely important (*SI*)", "important (*I*)", "very important (*VI*)", and "I don't know". The four alternative answers were rated using a four-point Likert scale, from the most negative ($score_{NI}$ = 0, "not important") to the most positive ($score_{VI}$ = 3, "very important"). We considered the answer "I don't know" a missing value.

For each dune habitat we assessed the supply of Recreational value(RV_{ES}) based on the observed answer frequency (n_{VI}, n_I, n_{SI}, n_{NI}) compared with an hypothetical situation in which all the interviewees give the most positive answer as follows:

$$RV_{ES} = {RV_{OBS} * score_{MAX}}/{RV_{MAX}}$$

With $RV_{OBS} = \sum N_a * score_a$ given by Na (the frequency of each alternative answer: nvi, ni, nsi, nni) multiplied by scorea (the respective ES scores: 3, 2, 1, 0). RVMAX is the number of questionnaires multiplied by scoreMAX (3). RVES varies from 0 (no ES supply) to 4 (all interviewees assigned the maximum score).

In order to derive a spatialized value of ES for each year (1986 and 2006), we multiplied the recreational value of each natural dune category (RVES) derived from the interviews by their extent (ha) in the study area and then we summed up the obtained ES values for each of the compared years. We assumed that the perception of natural features has not changed over time.

Urban expansion and R&TES loss

We assessed variation in ES capacity due to urban expansion based on the ES values estimated for each natural dune category, and its cover loss due to the transition from natural to artificial surfaces over time. After describing the extent in ha of coastal dune ecosystems and of urban areas over time, we quantified urban expansion into natural dune categories by transition matrices (Turner and Ruscher, 1988).

Results

Recreational value

The profile data of the 591 questionnaires showed that the interviewed public was quite heterogeneous with no dominant gender and coming from widespread proveniences (Table 1). More than 55% of the interviewees consider dune habitats very important (70.6%: BPV, 57.5%: DHV, 55.2%: DWV) (Table 2). Furthermore, for more than 80% of the interviewees, BPV, DHV and DWV are either important or very important, highlighting that natural coastal dunes provide very high Recreational value.

Table 1. Respondents' profile in terms of gender, age, education, place of residence and job.

Social descriptors	%
Gender	
Male	48
Female	52
Age	
<19	2
19-60	84
>60	14
Education	
Primary school	5
Secondary school	60
University	35
Place of residence	
Local	60
Other regions	40
Job	
Employed	50
Freelance	22
Retired	9
Student/homemaker	17
Unemployed	2

Table 2. Frequencies of the alternative categorical answers (*Na*) to the question concerning people's perception towards the natural features present in the coastal sites. Numbers and percentages (%) synthesize the response to the question "How important do you consider the following natural features?" BPV: *Beach with Pioneer annual Vegetation*, DHV: Dunes with *Herbaceous Vegetation* and DWV: Dunes with W*oody Vegetation.*

	BPV		DHV		DWV	
	Na	%	*Na*	%	*Na*	%
Very important	417	70.6	340	57.5	326	55.2
Important	132	22.3	155	26.2	145	24.5
Scarcely important	26	4.4	55	9.3	60	10.2
Not important	6	1.0	31	5.2	48	8.1
I don't know	10	1.7	10	1.7	12	2.0

The RV_{ES} in all the analyzed coastal dune natural habitats is very high (Table 3) and ranges from 3.65 for the seashore to 3.29 for the inner wooded dunes.

Urban expansion and RV_{ES} loss

The extent of natural dune categories and of urban areas in the coastal landscape varied through time. A consistent increment of artificial areas occurred during the last 20 years with ~12% of increment and an annual rate of 0.62% (see for details Malavasi et al 2013).

Using the measured ES values, we calculated a net loss of $R\&T_{ES}$ (globally ~93.25) in the last 20 years. Artificial surfaces expansion occurred in the three natural dune categories with different rates and altered ES supply heterogeneously within the coastal mosaic (Table 3). Land take strongly affected wooded dunes causing an important loss RV_{ES} supply (~ 15% loss) (Table 2). On the other hand, embryonic shifting dunes, characterized by high RV_{ES} values, being less affected by artificial surfaces, underwent a minor loss in ES supply (~9%).

Table 3. Cover values (ha) for each natural dune category on the comered years (Cover 1986 and Cover 2006) and relative along with the estimated Recreational value supply (RV_{ES}). Natural dunes loss (ha) and $R\&T_{ES}$ loss due to artificial surfaces expansion for each of the natural dune categories for the analyzed period are also reported. BPV: Beach with Pioneer annual Vegetation, DHV: Dunes with Herbaceous Vegetation, DWV: Dunes with Woody Vegetation.

Natural dune habitat	RV_{ES}	Cover 86 (ha)	RV_{ES} 86	Cover 06 (ha)	RV_{ES} 06	Natural dune loss (ha)	RV_{ES} loss
BPV	3.65	42.80	156.23	39.16	142.93	3.64	13.30
DHV	3.36	67.39	226.42	62.27	209.23	5.12	17.19
DWV	3.29	135.01	444.20	115.94	381.43	19.08	62.77
Overall			826.85		733.60		93.25

Discussion and conclusion

In the analyzed area, artificial surfaces expansion played an important role in shaping coastal dunes. Such process, observed in many coasts worldwide (EUCC, 1998; Malavasi et al., 2013; Schlacher et al., 2007), has negatively affected the capacity of coastal dunes to provide important ecosystem services as recreational and cultural services.

Mediterranean coastal dune systems have high RV_{ES} supply values that vary across the different habitat types located along the sea-inland gradient. BPV, being highly chosen for escape and recreation (Doody, 1997; Everard et al., 2010) were evaluated as very important for up to the 70% of the visitors, confirming their key role in supplying the recreational value. DHV and DWV also have a considerable RV_{ES} being a support area for several open air activities as walking, jogging and relaxing.

The observed coastal artificialization process greatly altered natural dune vegetation types in a distinct manner. In the last 20 years urban sprawl strongly hit Wooded Dune Vegetation and Herbaceous Dune Vegetation and to a minor extent it cosummed the Beach with Pioneer annual Vegetation, leading to a meaningful loss of $RV_{ES.}$ The continuous expansion of holiday houses and bathing facilities should be considered of serious concern for the coastal environmental sustainability. Moreover, the economic costs incurred to tackle coastal erosion and the shrinkage of beaches (resources that support tourism) are also very high (Romano and Zullo, 2014).

Our work underlines the fragility of natural coastal dunes that during the last decades have been progressively replaced by artificial areas, with a direct impact on their capacity to supply ES. In particular, the work shows a paradox. Actually, while coastal dunes have become a privileged destination for sea-side tourism, their recreational value has decreased in the same time. Indeed, the coastal tourism industry often depletes the services on which it depends (Drius et al. 2019), The observed artificialization is most likely related with the absence of adequate and efficient regulation policies for controlling the changes in land use and the expansion of urban and suburban areas. The observed urban sprawl not only reduces the extent of natural EC habitats and their unique biodiversity with a consequent reduction in ES supply, but it also boosts the action of many other threats on the remaining natural dunes, compromising their survival over time. Thus the apparent economic gains promoted by urban sprawl are surpassed by long lasting losses. This considered, the urban development projects along the coasts should consider the important non-market economic losses that occur when natural ecosystems are lost or transformed and the need of preserving the coastal vegetation zonation as a whole.

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Wave climatology and energy transport as an assessment tool for coastal erosion mitigation solutions

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Coastal erosion along Tuscany shoreline has received increasing attention in recent decades, due to its importance in coastal management activities required by a growing demand for recreational areas together with a safe planning of coastal protection strategies. A number of studies [11-14] have addressed specific budgetary problems and shoreline response in northern Tuscany, while less focus has posed on the south-adjacent physiographic unit, i.e. from Punta Lillatro to Torre Nuova. Past (1984-2005) and recent (2005-2010) coastline evolution data were recently reanalyzed [15] and compared, mostly using photogrammetric techniques. Although very useful knowledge can be gained on the general trends of the aforementioned physiographic unit, the different time ranges adopted for the comparison pose a limit to the reliability of data in terms of statistical robustness. Evolution trends computed on a shorter time span can be significantly altered by the short-term variability, which is possibly balanced in the longer time span data. The erosion/accretion occurring in these areas were studied, in previous works, from a geomorphology and sedimentary perspective. However, the inherent complexity of sediment transport phenomena involving non-linear processes and wave-induced mechanics, motivates the interest in providing a systematic assessment of wave climate conditions throughout the coastal zone at unprecedented high resolution and on a relevant time span. Wave action directly influences sediment pick-up, and wave induced currents can cause a significant long/cross-shore transport, with more energetics waves potentially having a greater impact.

This work aims at estimating the wave-induced energy transport towards the coast (with focus on the coastal section from Punta Lillatro to Mazzanta as study site) on a multi-year seasonal mean time scale, with a spatial resolution impossible to achieve by currently available hindcast data. Such an estimation allows to identify which coastal portions of the study site are interested by a higher energy transport with respect to the adjacent ones, providing potentially suitable areas for the application of mitigation approaches based on wave-energy transport reduction. With this work we also aim at providing additional information to the geomorphology and sedimentary results previously found, serving as a preliminary framework for future studies at the local scale. At this stage it is not completely clear whether the most energetic coastal sectors are exactly the same affected by the most severe erosion, due to the interplay of many factors involved in the process, for which it is difficult to disentangle the effects. Our goal is instead to give an additional perspective on the possible causes of erosion along the selected shoreline, for which a detailed analysis of the wave energy transport was unaddressed so far. Accounting for this wave-energy transport effect into shoreline evolution traditional studies could improve the efficiency of protection actions.

The wave-climate characterization for the selected area is carried out on hourly hindcast data at 1/24° horizontal resolution spanning 10 years (December 2006 to December 2016) from the available hindcast product of the Mediterranean Sea Waves forecasting system WAM 4.5.4 [1]. The relevant used wave parameters include spectral significant wave height (Hs), mean wave direction (MWD) and wave period at spectral peak (Tp). Spatially averaged time series on hourly basis and spatially varying multi-year seasonal means are computed on the original grid. Data are additionally smoothed on a boundary fitted curvilinear grid via linear interpolation, a new refined bottom topography is generated from the gridded data sets provided by GEBCO[2]. A seasonal variability of Hs is found over the entire area, with the highest offshore significant wave height occurring in winter. The same spatial pattern of significant wave height persists for all the seasons but with a sensitive seasonal variation of absolute values. Tp shows a sensitive seasonal response with longer periods associated with winter higher wave heights. Mean wave direction and principal direction at spectral peak are consistent with a west-facing coastline, the prevailing incoming direction is S-SW for the winter climatology, rotating SW-W during summer.

The obtained statistics is finally used to force a set of high resolution numerical simulations to better account for the shallow water effects occurring at finer spatial scales in the coastal area, and a nesting procedure is adopted to resolve the wave parameters approaching the coast of the study site. This is aimed at improving the limitations due to a poor representation of the small-scale morphological features in the available data. The

numerical results are used to provide an estimation of the net onshore energy transport, in order to identify which portions are the most energy-stressed.
A high resolution SWAN numerical model is used to transform the offshore waves towards shallow waters. The evolution of the wave spectrum is dominated by the spectral action balance equation according to Hasselmann et al[4]. The combined effects of sources and sinks for the energy density spectrum are included in the model, which accounts for energy input by wind, energy dissipation by bottom friction, whitecapping, depth-induced wave breaking, and non-linear wave-wave interactions. The model equations are discretized on a geometrical and spectral computational grid and the action balance equation is integrated with finite difference schemes in all five dimensions: time, geographic space and spectral space. Upwind schemes in geographical and spectral space are used, supplemented with a second order central approximation in spectral space to improve spectral accuracy.
The numerical model is applied to an overall area and a localized domain. The former is chosen to be large enough around the study site for the open boundaries to be distant to avoid introducing spurious numerical errors that may arise along them. The localized area is chosen to greatly increase the spatial resolution around the test site.

The spatial discretization uses a land boundary-fitted curvilinear grid covering the overall area with a horizontal resolution of 112x55 grid points, finer near the coastal bathymetric changes.
Boundary conditions on Hs, Tp and MWD are imposed as obtained by interpolation of the hindcast data after the decadal seasonal climatology is computed. The model is forced by a space varying wind computed according to the seasonal climatology over the decade 2006-2016. A nesting procedure is adopted to resolve the details of the coastal region within the localized domain. A finer grid of 523x63 unequally-spaced grid points, finer near the coast, is nested into the overall domain. For both the overall area and the nested domain numerical simulations have been carried out to cover the four seasonal climatology conditions. Output of Hs, Tp, MWD, and wave-energy transport are computed.
The seasonal climatology output of Hs and energy transport for the nested model shows a clear seasonal variability in accordance with the behaviour obtained from the statistical analysis, but a much finer bathymetric-induced spatial pattern is found. The winter season is found to be characterized by the strongest average energy transport, which we quantified on a seasonal mean timescale. The winter energy transport towards Punta Lillatro-Mazzanta coastline reaches more than twice the summer values. A better representation of the spatial variability of wave-energy transport on small scales associated with bathymetric effects is particularly noticeable throughout the coastline and persists all year round.
We numerically quantified the multi-year seasonal means of the onshore energy transport along four different isobaths within the depth of closure for a length of 12km measured separately on each isobath, starting south of Mazzanta and covering the chosen study site towards Castiglioncello. We tracked its spatial variability along each isobath for all the seasons and detected the value and location of the energy-transport maximum peak at all the considered depths.

We additionally performed one single numerical simulation of an extremely-rare wave storm event recorded offshore by the original hindcast dataset previously analyzed[1]. Time-varying boundary conditions (storm) are applied at the overall-model, and the output from the high resolution nested domain is used to compute the time-varying energy transport on each computational grid point. Its value along the above-selected isobaths is analysed as a (i) time average-spatially varying field and (ii) spatially-averaged-time varying field. The former allows to identify which portion of each isobath is on average the most energy-stressed during an extreme event. The latter allows for a segmentation of each isobath in shorter sections and an estimation of the time evolution of the normalized energy transport in each one, or the fraction of the total available energy which is transported through each isobaths-section with time during an extreme event.
As an additional tool to calibrate key numerical parameters, the new technology 'Wave Radar' has recently received increasing interest in the field of coastal monitoring for surveillance and management of emergency situations. The Wave Radar works only with short pulses, the transmission is inhibited towards land and it has a narrow only-seaward angle of emission, irradiating at non-uniform time intervals only in correspondence of high swells. This enables the acquisition of an adequate amount of data, to analyse waves and surface currents up to 3 nautical miles seaward from the installation site. The ability to know the sea surface state in real time and with good accuracy allows to deploy a series of applications and tools, such as shoreline evolution monitoring, erosion rate assessment and tuning of numerical models. The combined use of on-site data extraction and computational modeling could provide a valuable improvement in the quantification of energy transport-related issues relevant to coastal erosion mitigation solutions.

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Pre- and post-storm sedimentological characterization of an artificial coarse-clastic beach

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Introduction

Coarse sediments are increasingly used as a viable option for beach fill interventions because they are less subjected to wave motion processes relative to finer sediments such as sand. Therefore, coarse-clastic beaches are perceived as being more stable than their sandy counterparts and providing a higher protection level, especially where sandy beaches have been completely wiped out by erosion processes (Buscombe and Masselink, 2006). In these situations, a replenishment carried out with native sediments would not withstand the energy of the processes that led to the initial loss of the beach, and likely nullify the benefit of the replenishment and its considerable financial outlay. Even though some studies already pointed out significant motion of pebbles in the swash zone under fair-weather conditions (Bertoni et al., 2013; Grottoli et al., 2015; Grottoli et al., 2019), coarse sediments succeed where sand does not. In many countries coarse sediments have been used to refill an eroding coarse-clastic beach (e.g., Nice, France; Portonovo, Italy), or alternatively to replace a sandy beach (e.g., Marina di Pisa, Italy). The downside of such protection schemes is that our knowledge of coarse-clastic beaches, in particular artificial ones, is far from satisfactory. Lately scientific interest in this environment has spiked (Kumada et al., 2010; Grottoli et al., 2015; López et al., 2018; Pikelj et al., 2018), but some aspects are yet to be fully investigated and understood. Grain-size distribution is a primary facet that needs specific attention: choosing the right fill material is a priority for project designers, in terms of both mineralogical and sedimentological properties (Grottoli et al., 2019). Mineralogical composition is paramount especially for sand replenishments, where a mixture of native and alien sands is often considered by local communities to be as much of a problem as the erosion processes. Sedimentological properties such as grain-size and sorting are crucial for a good coarse beach fill, because sediment variability on the shore is a function of wave processes. In this paper, the definition of grain-size distribution patterns on an artificial coarse-clastic beach before and after a storm is addressed using digital analysis of a series of surface images. The beach is located at Marina di Pisa, which is in the central sector of Tuscany (Italy). Marina di Pisa experienced serious erosion processes since 1850 due to a drastic reduction of Arno River sediment bedload (Pranzini, 2001). As this was the only sand source for the area, the intense coastline retreat ended up threatening the village. Along with hard protection structures such as groynes and breakwaters, in the early 2000s a series of coarse-clastic beaches were built to prevent further land loss and restore the tourism economy (Nordstrom et al., 2008). The artificial beaches, made of marble pebbles about 40-to-90 mm in diameter did work well in terms of coastal protection, even though issues about filling material mass loss raised concerns (Bertoni et al., 2016). Such a sedimentological characterization could suggest potential improvements to future coarse beach fill schemes for making rational choices in the planning phase of the intervention.

Methods

Three transects were designated with DGPS on a 150 m long artificial pebble beach at Marina di Pisa for the photographic grain-size analysis. The first survey was carried out on October 15th, 2018, and the second on November 15th, 2018. Both surveys were performed under fair-weather conditions and with no wave motion. A 44 cm square frame (for photo calibration and scaling purposes) was moved along the three transects and photographed. In the November 15th survey the same procedure took place, but a tape measure was also extended 30 m underwater extending the central transect by a SCUBA diver swimming on magnetic bearing 270º. The square frame was photographed in the same way as before, excepting areas where debris from dead Posidonia sp. grass covered pebbles, and in the surf zone where waves and shallow water depth obstructed photography. The photographic data was then post-processed and analyzed with pyDGS, an open-source Python framework that uses a continuous wavelet transform method to automatically estimate grain-size from images (Buscombe, 2013). The results produced arithmetic mean grain size values and standard deviation or sorting values. The accuracy of the program within the limits put forth by Buscombe (2013) was verified by several photographs of test pebbles whose axes were measured with a caliper and then analyzed by pyDGS. These test photographs and two field photographs were also measured digitally using the CPCe coral counting software (Kohler & Gill, 2006), since caliper measurements of the underwater survey zone was not practical. This calibration process, in addition to verifying the applicability of pyDGS to this dataset, will hopefully provide some assessment of the impact on the program's analysis of imaging issues arising from limited visibility in the underwater zone due to backscatter of sunlight on silt particles in shallow water, optical distortion, and larger floating particles of seaweed and debris in the water column.

Results and Discussion

Grain-size data provided by digital image analysis allowed us to characterize the sediment distribution on the surface of the artificial coarse-clastic beach at Marina di Pisa (Fig. 1). The current results focus on terrestrial data; though our underwater data is promising, it is not possible to make conclusions about sediment distribution changes from only one underwater survey day. Special care should also be taken when using an automated, algorithmic approach to compare terrestrial images obtained in good lighting conditions to underwater images from an environment with marginal visibility and increased optical distortion.

The terrestrial results show that grain-size is generally coarser on the October 15th, 2018 survey compared to that of the November 15th, 2018 survey. This trend is evident especially on the central and southern transects, where the average grain-size is often around 10 mm coarser in October. The November configuration was determined by a storm that occurred on October 30th, 2018, when the wave buoy located 8 km north of the study area recorded wave heights exceeding 3 m, which can be defined as a mild-to-intense event (Fig. 2). As differences in grain-size are reported also close to the seawall, storm surge reached the upper level of the backshore, reworking the sediments throughout the whole beach. Even though profile steepness did not change significantly, beach width increased in November along the northern transect, whereas it decreased in the central and southern transects. As the wave gauge revealed that the storm came from southwest, wave direction would be in accordance with a net northward movement of the pebbles. This notion can also be confirmed by the sorting, which is poorer along the northern transect in November (Fig. 1). Grain-size comparison before and after the storm suggests that a medium-energy state would lead to a decrease in average sediment size, implying a seaward movement of coarser pebbles. This trend has already been reported on mixed sand and gravel beaches, where gravel tends to move down along the beachface during storms and back up during storm decay (Sarti & Bertoni, 2007; Ciavola & Castiglione, 2009). As the beach at Marina di Pisa is not subjected to anthropogenic practices such as artificial flattening or scraping, the coarser configuration of the October survey should then be determined by some other energy state capable of moving the coarsest particles while forming definite storm berms.

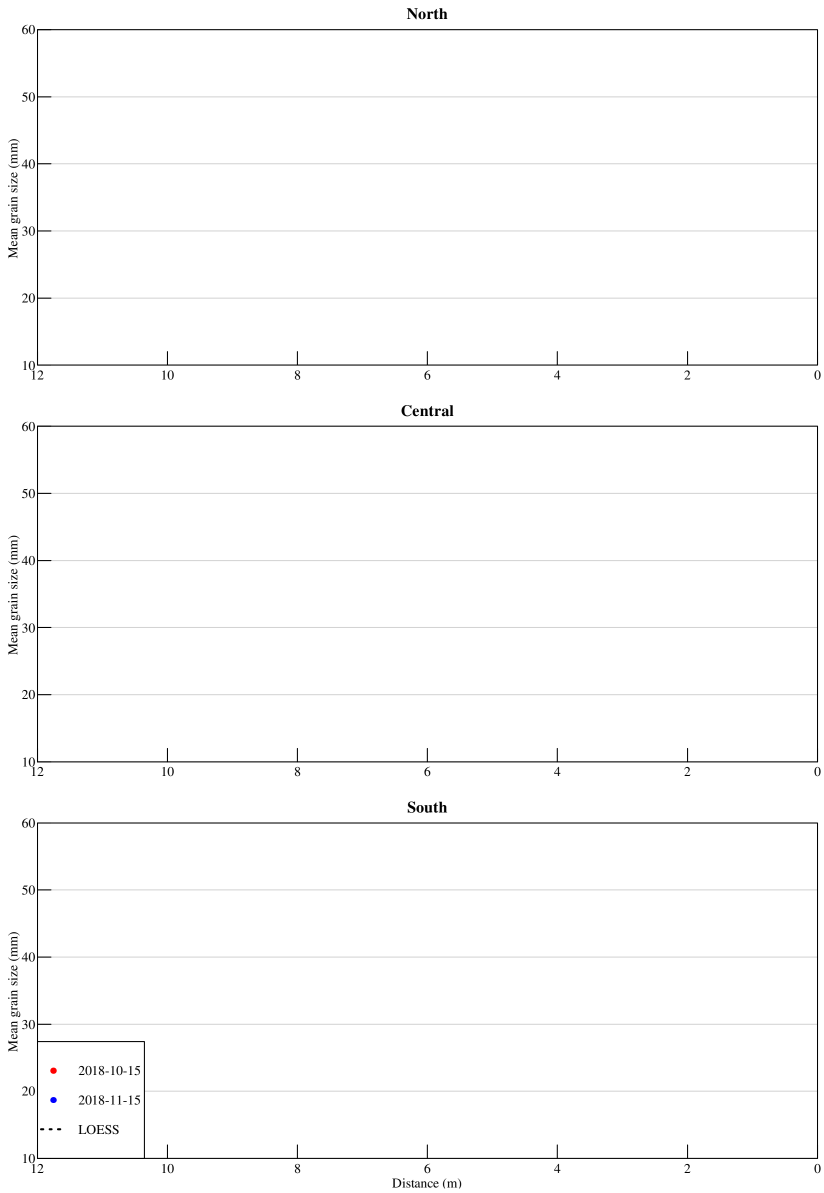

Figure 1. Y axis shows mean grain size in mm along north, central, and south transects on two survey days as calculated by pyDGS (Buscombe, 2013). Position on beach in meters shown on x axis. Higher x values are seaward (west). Only points on the backshore, not the surf zone or underwater, are shown in this figure. Size of points indicate sorting, as represented by the standard deviation of mean grain size calculated by pyDGS. Larger points are less sorted. Smaller points are more sorted. Lines show each series smoothed with LOESS to aid interpretation and highlight differences between subsequent surveys.

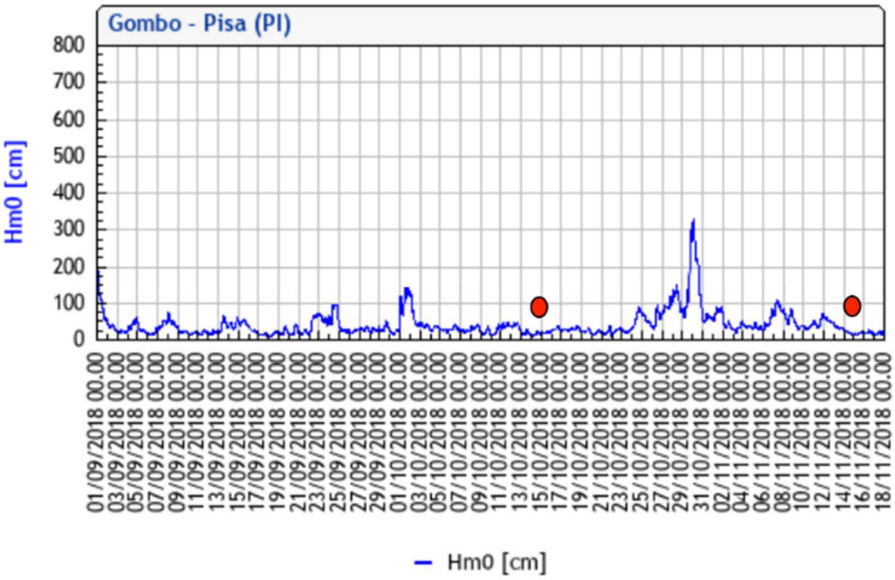

Figure 2. Plot of the wave height in a two months timespan. The red dots indicate the dates of the surveys. Wave height patterns confirm that no major high-energy events occurred in the weeks leading to the October 15th survey (retrieved from the website of Centro Funzionale di Monitoraggio Meteo Idrologico – Idraulico, Regione Toscana).

Conclusion

Grain-size analysis is the most characteristic technique to define the textural parameters of sediments; digital grain size tools proved to be reliable, allowing us to analyze multiple sectors of the beach with no gaps along transects in relatively short timespans. Our sedimentologic characterization of an artificial coarse-clastic beach at Marina di Pisa indicates that a medium-energy event still reworks the whole backshore, and coarser particles move down along the beachface. As those coarse size clasts can be entrained only by intense fluxes, they cannot be moved back up during the post-storm phases. Further investigations are needed to get more insights, as the submerged beach should display coarser grain-sizes if pebbles actually tend to shift seaward. Though our preliminary underwater survey data does indicate much coarser pebbles, it is crucial to perform additional surveys following storms so that distribution changes can be better quantified in the submerged zone.

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*Reuse of dredging sediment: the case study of "*Marina Sveva*" port – (Italy)*

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Introduction

This documents aims at summarizing the methodology for the planning of dredging activities of the "Marina Sveva" Port in the Montenero di Bisaccia (Italy). The works rely on the reuse of dredged sediment as sand mining for nourishment purposes in compliance with the national rules (i.e. DM 173/2016 dealing with the criteria and methods for reusing of dredged sediments)

The analysis of the coastal stretch in close proximity of the harbor highlighted the critical issues related to strong erosion phenomena. Then, nourishment interventions with sand from the dredging works of the "Marina Sveva" port were identified as effective works to be carried out. On one hand, dredging works were foreseen to avoid critical issues related to the navigation safety due to the reduced draft at the approach channel (i.e. silting phenomena). On the other hand, characterization and classification of the sediments revealed that disposal of the dredged material at the neighboring coastal stretch is possible.

This document therefore describes an example of the use of the "sand" resource coming from the excavation of harbor with adequate chemical-physical-environmental characteristics for the nourishment in the same coastal area undergoing coastal erosion in the recent years.

Description of the case study

The Touristic Port "Marina Sveva" is located (Figure 1) at the center of the physiographic unit between the headlands of Punta Penna to the north-west (about 13,5 km far) and Termoli to the south-east (about 18,5 km far) for about 34 km of extension. The harbor is located in the mid-coast area of the Montenero di Bisaccia (Middle Adriatic Sea, Molise Region), less than 600 m from the limit with the Abruzzo Region and therefore represents the first port of the Molise Region for the navigation routes coming from the north and the middle Adriatic Sea. The large scale geomorphological structure is characterized by theafore mentioned headlands and from the Trigno River mouth (just 1 km apart the harbor).

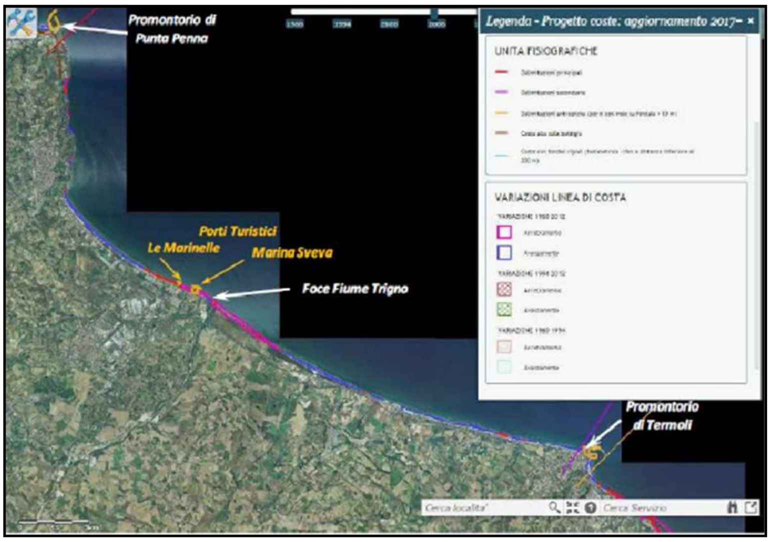

Fig. 1 - Geographical location of the study area (source: National Geoportal managed by the MATTM)

The overall configuration of the coastal stretch is the result of complex morphodynamic processes between the fluvial sediment transport from the Trigno river and the sediment transport forced by wave action. In the past, the coast has been fed by natural sand due to the prevalence of the fluvial sediment transport on the local sediment budget. Starting from the second post-war period, particularly in the last decades, with the reduction of the fluvial contribution to the sediment budget (related to the construction of dams and interventions of hydro-geological and watershed restoration along the Trigno river area), erosion phenomena along the coast near the river mouth increased.

Marina Sveva is located on the west of the Trigno mouth (on the hydraulic left), with the lee breakwater is to about 500 m west. Specifically for the area of interest (from the "Formale del Molino" to the "Mergola Torrent") there are twocoastal features: alluvial plain and sloping straight coastline with the tendency of the backing shore line (see Figure 2). From 1954 to 2003,the whole area, underwent erosion that caused a total loss of emerged beach of about 672,000 m² with an average retreat of the shoreline of 90 m, with a maximum value of 160 m (Pietro PC Aucelli et al., 2009).

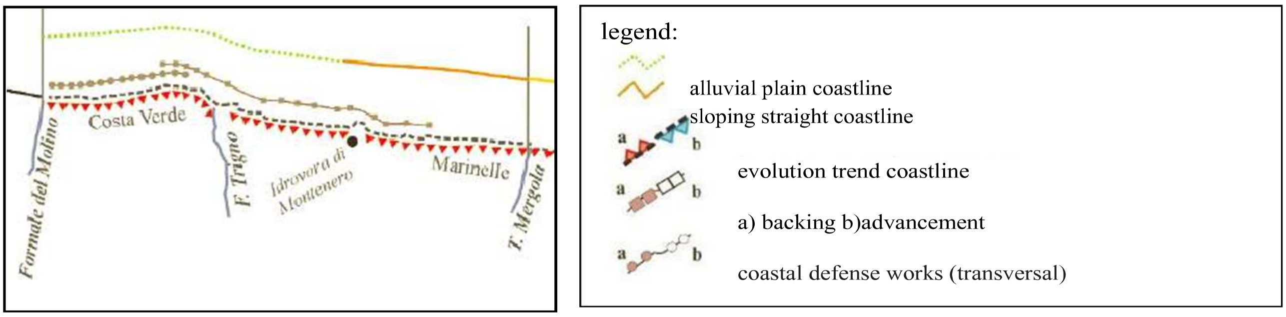

Fig. 2 - Coast types, evolutive trends and coastal protection structures present along the Molise coast (Aucelli et al., 2009)

Dredging area

The dredging area is along the access channel (A in Figure 3) and inouter harbour (B in Figure 3) of the "MarinaSveva" Port.

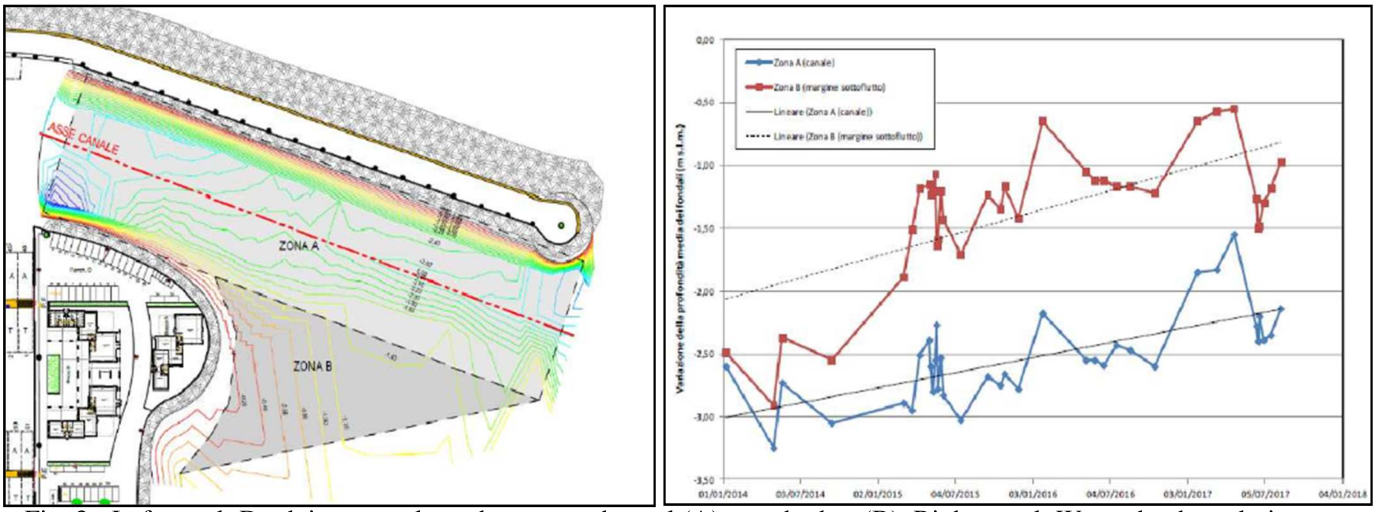

Fig. 3 - Left panel: Dredging area along the access channel (A)outer harbor (B). Right panel: Water depth evolution at the access channel (diamonds) and at the outer harbor (squares).

Field data have been collected in the past, fora total of 36 depth soundings performed from January 2014 until August 2017 by the personnel of the Marina. A bathymetric and topographic survey with SB combined with an RTK GPS (October 2017) was carried out. The analysis of the variation of the average depth, revealed a strong decrease of water depth at the dredging areas.

In particular, even if annual dredging interventions were carried outwith a maximum of 5.000 m³/year the company SMM SpA which manages the Marina, average decreases of 30 cm/year and 50 cm/year were estimated for area A and B respectively. Nevertheless, a decrease of 20 cm/month was estimated in the recent period for area A.

Characterization and classification of dredging area

The estimated dredging volume is lower than 40,000 m³, therefore the procedure of characterization and classification according to the national rule may be carried out within a simplified procedure.

For the dredging materials, various types of analysis (ecotoxicological, chemical, physical, biological) have been carried out. They aim at defining the severity class of the ecotoxicological hazard (resulted as ABSENT) and the severity class of the hazard for the chemical hazard index (resulted as ABSENT - TRANSFERRED and LOW), The sieving analysis revealed that the material is characterized by prevalent sandy fraction between 81.4% and 91.6%, a microbiological values within permitted limits (in particular Salmonella, which with regard to the health aspects can be considered the most important among the biological parameters, was observed to be absent). In particular, the sediments analyzed in the dredgingarea are of class A and in compliance with the national laws the dredged material can be used for nourishment purposes (emerged nourishment if fractions of peliteis less than or equal to 10% and submerged nourishment if fractions of pelite is greater than 10% but with a prevalent fraction ofsand).

Material management: beach nourishment

Four nourishment areas were identified (R1 - R2 - R3 - R4 in Figure 4). The area R4 (close to the mouth of the Trigno river) has been identified as a priority area.

Fig.4–Locations of the nourishment areas

Analyses similar to those carried out for the characterization of sediments in the dredging area has been performed also for the nourishment areas. The results revealed that the environmental characteristics (ecotoxicological, chemical, physical and microbiological) of dredging area sediments are compatible with nourishment area sediments in compliance with the national rules.

Indeed, the sediments of dredging area likely came from the same coastal area, hence of the beaches to be nourished.

Works technical details

The technical details of the works follow. The total dredging volumes for the first year is equal to 16.248,00 m³, of which:

10,923.00 m³ from the area A-channel for a final depth of the 3.00 m,

5.325,00 m³ from the area B-outer harbor for a final depth of the 2.00 m.

The foreseen nourishment volumes are expected to be greater than dredged volume. Indeed, they are at least 52,000.00 m³, of which R1 = 30,000.00 m³, R2 = 2,500.00 m³, R3 = 3,000.00 m³ and R4 higher than 16,500.00 m³. Then, a dredging maintenance plan with annual dredging rates of 5,930.00 m³ for a total of 39,968.00 m³ has been foreseen for the next four years.

Depending on the characteristics and quantities of the sediments in dredging areas and beach nourishment (emerged / submerged), the dredging and nourishment activities will be carried outby:

maritime equipment for the dredging works, transport, flooding phase and submerged nourishment;

terrestrial equipment (excavator, dozer, etc.) for the handling of pipes and for emerged nourishment. In according with national rules, the allowable dredging methods are either mechanical or hydraulic, but also combined. In both cases the dredging phases will be gradual without improper localized excavation and it will proceed by continuous layers.

Considering the excellent quality of the materials, all of class A, it is not necessary to implement specificwork procedures differentiated in different areas and in different dredging depth.

Technologies and methods of work will be used to minimize sediment dispersions and localized excavation so as not to influence the wave dynamics and currents.

In fact, to minimize the possible effects of turbidity, it is necessary to use dredging systems and equipment which can be defined as "environmental" equipments Trailing Suction Hopper Dredgers (TSHD) and maritime equipment with loading hopper and excavators with environmental buckets to avoid sediment dispersion. Theseequipment are able:

to allowa selective dredging minimizing turbidity;

to avoid improper localized excavation;

to minimize the amount of dispersed fine sediments;

to minimize the disturbance to the environment;

to transport the material in safety conditions, i.e. not causing accidental spills along the dredge routes and providing for the use of absorbent panels if there are any accidental spills;

to control all dredging operations by using accurate navigation equipment and positioning tools, based on satellite type technologies;

to optimize the work phases according to the intervention techniques and the equipment used to reduce the duration of the works;

to analyze and optimize the planned nourishment (identifying the optimal sand supply per linear meter of beach m^3/m with specific maritime and coastal engineering studies that take into account the wave, currents and any external factors influence - such as drains for rainwater or channels);

to reducetheworkduration including the possible combined use of maritime equipment.

Concluding remarks

This document illustrates a summary of the dredging works design (excavation). The works must be made to allow a safe access to channel of Tourist Port "Marina Sveva" and to nourish the neighboring beaches currently affected by strong erosion phenomena.

The intervention, foreseen along a coastal stretch of the Molise Region in the Montenero di Bisaccia village (Molise), has been then planned in compliance with the national rules.

A series of in-situ investigations were performed, and a series of studies activities have completed in order to gain insight about the procedure to follow to reach the goal of the project. The results revealed that a simplified procedure suffice. In fact, the total volumes are less than 40,000.00 m^3 andthe port is of the tourist type.

The study activities have defined that:

the dredging area is mainly access channel and marginally the outer harbor;

the dredging volumes amount to a total of 39,968.00 m^3 (16,248.00 m^3 for the first year and depth of -3.0 m) and amaximum of 5,930.00 m^3 / year for the next four years (for a total of 23,720.00 m^3) to ensure the maintenance of the water depth atthe entrance of the harbor.

After having identified and framed the dredging area, the necessary characterization and classification activities of the excavation area materials have been planned and implemented.

Therefore, in compliance with the national rules, specific analyses were performed and the sediments classified as belonging to the "class A".

Moreover, the analyses needed for the nourishment design revealed that also the sediment of dredging area belong to thequality class of A. The comparison of the analyses resultsobtained for sediments in the area of excavation and nourishment shown full compatibility from the environmental point (eco-toxilogical, chemical, physical and microbiological characteristics) required by the National rules.

Once the characteristics of the dredging and nourishment areas are known, the technical details have been defined in terms of the methods of excavation, transport and disposalwith appropriate equipment (maritime and terrestrial) in order to minimize the detrimental environmental effects during the works.

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Mid-term shoreline evolution and beach erosion along the southern coast of Gran Canaria Island (Spain)

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Introduction

Coastal areas, especially low-lying coasts, are generally of high strategic value for the economy and development of a country/region, but they are also very fragile systems, being frequently threatened by sea level rise, storms and subsidence and associated processes of erosion, inundation and flooding. The present work deals with the shoreline evolution and related beach erosion of the Gran Canaria Island, whose economy is strongly based on touristic activities that have developed especially along its coastline since the 1960s. Preservation of natural conditions and shoreline equilibrium is essential for the near-future development of the island. Our work focuses on the main low-coast sector of the Island, located in the southern-south-eastern sector and including a series of sandy beaches, among which stands out the famous Maspalomas beach and its dune system. This paper aims to highlight mid-term and recent shoreline changes and related critical aspects and trends.

Study area

The island of Gran Canaria occupies a central position in the Canary Islands archipelago, which is located in the south-eastern sector of the North Atlantic Ocean (Fig. 1A) near the north-western African coast. Almost circular in shape, with a diameter of 45 km, approximately, and a coastline length close to 280 km, it is characterized by a relatively steep relief and altitudes up to 1950 m. Major volcanic peaks are located near the center of the Island (see Pico de Las Nieves, Fig. 1B) and are deeply incised by a dense network of 'barrancos' (torrential incisions, canyons) that develops radially towards the coast. The coastline of Gran Canaria is dominated by high coast (Fig. 1B), mainly represented by low to high cliffs, widespread, especially along the western and northern flanks of the island. Beaches (gravel and sand beaches, pocket beaches) represent approx. 21.2% (60 km) of the total coastline and are concentrated along the southern and eastern sectors of the coast. These sectors are characterized by densely populated urban areas (Fig. 1B) and are particularly important for the economy of the Island, due to the large number of touristic activities and tourist-related infrastructures, which have been the primary cause of the deep alteration experienced by the coastline in relation to its original natural aspects, such as that of the San Agustin beach (Di Paola et al., 2011).

The climate of the Canary Islands is generally very stable and dry due to the influence of the trade wind belt and the Azores high although it is influenced by the North Atlantic Oscillation (Bechtel, 2016) and favours the tourism-based economy of Gran Canaria by allowing seaside tourism and sea-bathing practically throughout the year. Beaches are highly dynamic as the coast is under a meso-tidal regime, with a semidiurnal tide pattern and a tidal range between 2 and 3 meters. Regarding the wave climate, average conditions are rather mild, but with important local variations, due to the sheltering effects between islands and the orientation (exposure) of the different coastal stretches. The northern edge of the island is the most exposed to wave action, mainly approaching from the WNW-NNE directional sector and with a dominant sector being clearly in the N-NNE arc. Nevertheless, only approx. 25% of the sea states present significant wave heights (Hs) exceeding 2m. Average Hs reduces from north towards east and west and reach minimum values along the southern coast where more than 90% of the sea states have Hs lower than 1 m (Di Paola et al., 2017). Here, the predominant wave direction becomes the NNE-ENE directional sector but with a secondary preferred direction in the W-SW subsector, associated to a very low probability of occurrence (0.5%). This secondary preferred direction however includes all the sea states with Hs higher than 2 meters which can have important implications on coastal erosion and inundation of the sandy beaches. Most frequent winds affecting the southern coast come alternatively from the ENE and W directions, from October to April, and from April to September, respectively (Pérez-Chacón Espino & Máyer Suárez, 2007). Littoral drift is mainly in the N-S direction but with a clear and important reversal during sporadic wave storms approaching the study area with south component.

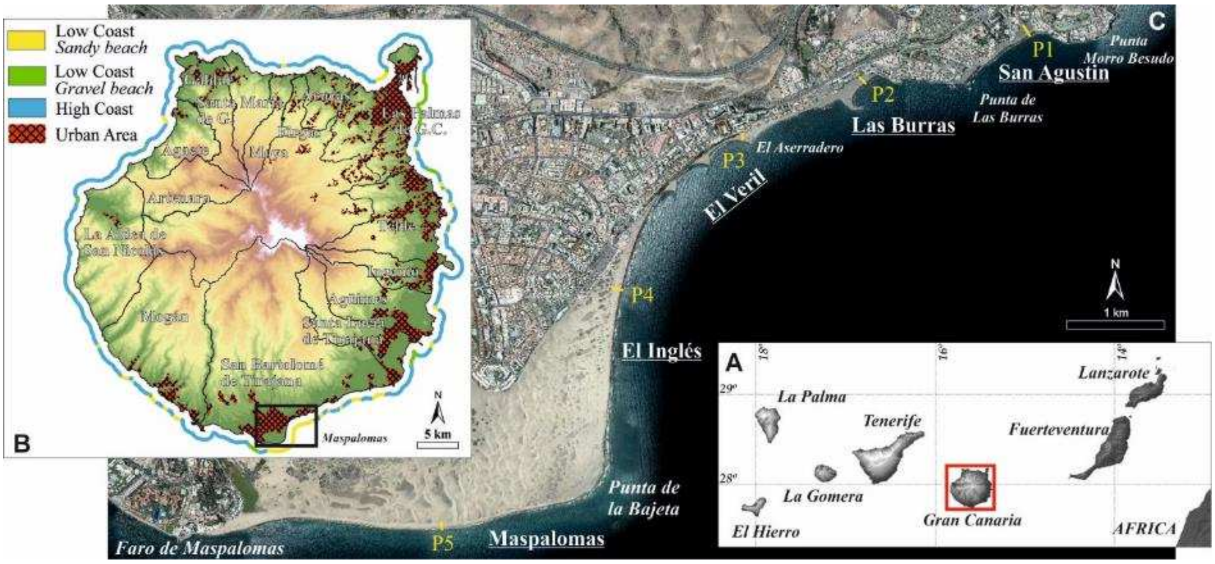

Fig. 1. (A) Location of Gran Canaria in the Canary Islands archipelago; (B) location of low and high coast sectors and major coastal urban areas of Gran Canaria;(C) location of the investigated beaches Maspalomas, El Inglés, El Veril, La Burras and San Agustin, and related beach profiles.

Data analysis and results

The five explored beaches (for location see Fig. 1) have been characterized in situ by GPS surveys, beach profiles (P1-P5, Fig. 1) and sedimentological analyses (Table 1) carried out in 2010 and 2016. These beaches have lengths of between approx. 300 m (Las Burras beach) and 3000 m (Maspalomas beach), their backshores and foreshores are several tens of meters wide width, extending in total for at least 100 m up to 130 m approximately. Foreshores are made of fine sands except for El Inglés beach, which is characterized by medium sands (medium grain size 0.384 mm, Table 1).

Beaches	Length m	Backshore width (m)	Foreshore width (m)	Foreshore slope – β_f (%)	Foreshore µ (mm)
San Agustin	634	42.6	83.2	3.74	0.224
Las Burras	291	47.9	81.0	3.62	0.185
El Veril	636	43.7	55.7	4.38	0.232
El Inglés	2441	49.7	83.0	3.56	0.384
Maspalomas	3056	59.9	69.7	3.98	0.246

Table 1. Main features of the investigated beaches.

Shoreline variations have been analysed by means of aerial digital photographs (GRAFCAN, 2018), considering the periods 1961-1998, 1998-2010, 2010-2016 and 1961-2016. In order to evaluate shoreline changes, the Digital Shoreline Analysis System (DSAS), which is a free available extension of ArcGIS (Thieler et al. 2009), has been used. This tool allows to create automatically regular-spaced transects along which shoreline positions of different age are compared. Through a Linear Regression Rate (LRR), applied to all the intersection points between the shoreline and each transect, shoreline variations were determined on 155 transects placed at an equidistance of 50 m.

Results derived from this analysis (Table 2 and Fig. 2) reveal significant differences among beaches in the shoreline evolution during the considered time interval of 55 years (1961-2016). Maspalomas beach has suffered a significant retreat especially in its central portion, where mean annual shoreline retreats exceed 2m/y, i.e. a total of 110 m. Even along San Agustin beach, shoreline retreat has slightly prevailed, with annual negative shoreline change rates being comprised between -0.07 m/y and -0.91 m/y (Table 2). El Inglés beach, instead, has remained substantially stable, while El Veril and Las Burras beaches have slightly prograded, although in a very inhomogeneous way.

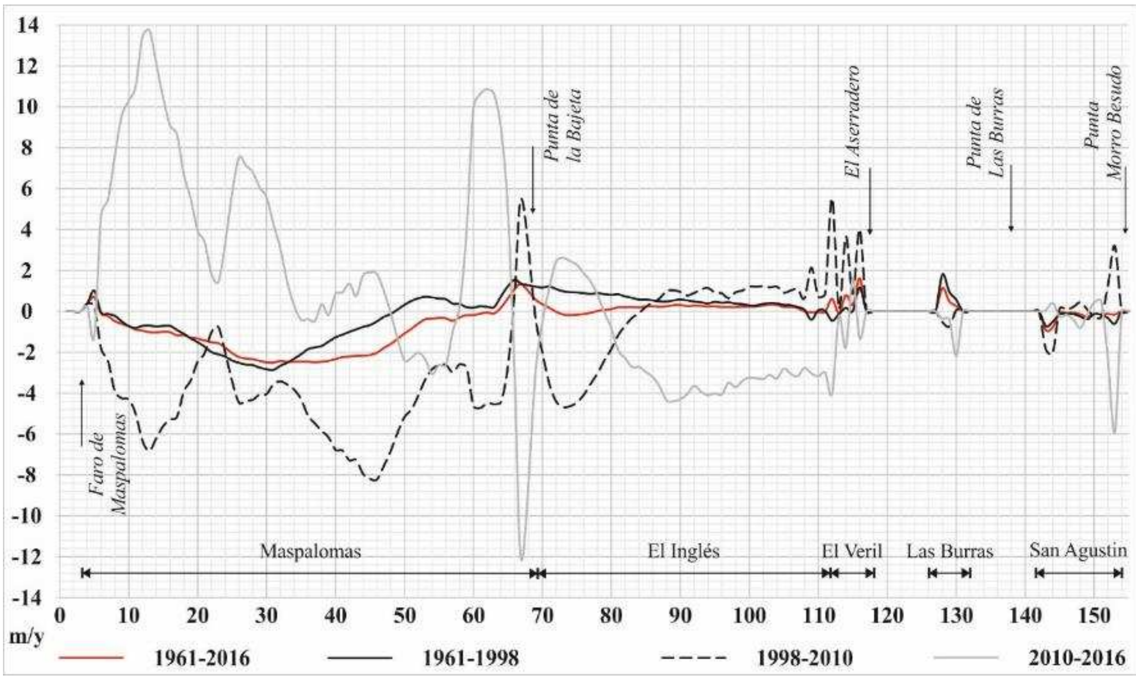

Fig. 2. Diagram showing the shoreline variations reconstructed for the investigated beaches for periods 1961-1998, 1998-2010, 2010-2016, and 1961-2916.

Shoreline evolution of the examined beaches during the approximately first four decades (1961-1998) is rather similar to that observed during the overall study period and therefore coherent to the observed mid-term shoreline trends. On the contrary, during the last two decades (periods 1998-2010 and 2010-2016) contrasting shoreline movements become evident. The period 1998-2010 is a period of significant beach losses especially for Maspalomas beach (Av = -4.12 m/y, Table 2), partially also for El Inglés (Fig. 2) and Las Burras beaches (Fig. 2, Av = -0.22 and -0.4 m/y, respectively, Table 2). San Agustin beach, instead, remains stable, while El Veril beach clearly advances, although in a non-homogeneous way. Here, the extension of the easternmost jetty and the construction from 2005 onwards of other two jetties (all oriented oblique to the coast) have clearly favoured such an inhomogeneous beach progradation by intercepting longshore drift coming from S.

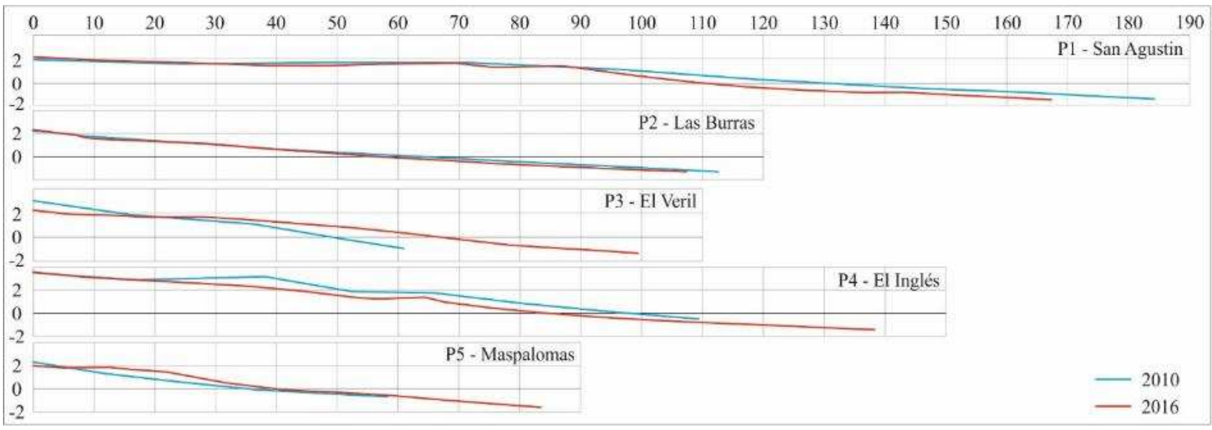

Fig. 3. Representative beach profiles. For location, see Fig. 1.

During the following period 2010-2016, both Maspalomas and El Inglés beaches are affected by a trend inversion that largely contrast with the precedent shoreline movements. Due to this trend inversion, Maspalomas beach largely recovers precedent beach losses (Av = 3.49 m/y, tab. 2) as also evidenced by the comparison of beach profiles carried out in 2010 and 2016, respectively (see representative profile in Fig. 3, for location see P5 in Fig. 1), showing also a topographic recovery of the beach. Conversely the other beaches largely retreat, especially El Inglés beach undergoes a significant beach loss (Fig. 2, Av = -2.22 m/y in Table 2), that largely resets precedent positive shoreline movements, and a related topographic lowering (see profile in Fig. 3, for location see P4 in Fig.1). El Veril beach, despite the presence of jetties that locally favour progradation (see profile in Fig. 3, for location see P3 in Fig. 1), is subject to local significant retreats and overall losses of -0.44 m/y (Table 2). Finally, also San Agustin and Las Burras beaches suffer moderate average shoreline retreats (-0.98 and -0.78 m/y, Table 2) as confirmed also by beach profiles P1 and P2 (Fig. 3, for location see Fig. 1) showing a slight trend to retreat and substantial stability, respectively. Prevailing negative shoreline trends of the easternmost beaches during this period highlight their high fragility and, possibly, some increase of wave dynamics that majorly has affected the eastern sector of the study area.

These two periods, besides contrasting shoreline trends, are characterized by relative high shoreline change rates when compared to the previous period 1961-1998 and the overall investigated time window 1961-2016, highlighting an elevated and individual shoreline dynamic of the investigated beaches.

Beaches	**1961 – 1998**			**1998 – 2010**			**2010 – 2016**			**1961 – 2016**		
	Av m/y	**Min m/y**	**Max m/y**	**Av m/y**	**Min m/y**	**Max m/y**	**Av m/y**	**Min m/y**	**Max m/y**	**Av m/y**	**Min m/y**	**Max m/y**
San Agustin	-0.32	-0.72	-0.12	+0.09	-2.04	+3.20	-0.78	-5.91	+0.51	-0.26	-0.91	-0.07
Las Burras	+1.11	+0.57	+1.80	-0.40	-0.74	+0.05	-0.98	-2.19	-0.37	+0.63	+0.26	+1.14
El Veril	+0.31	-0.13	+1.17	+2.17	+0.14	+4.01	-0.44	-1.77	+1.61	+0.66	-0.08	+1.62
El Inglés	+0.54	-0.45	+1.22	-0.22	-4.68	+5.53	-2.22	-4.40	+2.61	+0.17	-0.18	+0.61
Maspalomas	-0.75	-2.86	+1.55	-4.12	-8.22	+5.50	3.49	-12.19	+13.75	-1.19	-2.51	+1.31

Table 2. Annual shoreline rates of study beaches during periods 1961-1998, 1998-2010, 2010-2016 and 1961-2916. Av = Average annual negative or positive shoreline variations (-/+); Min = maximum negative (-) and minimum positive (+) annual shoreline variation; Max = minimum negative (-) and maximum positive (+) annual shoreline variation.

Conclusive remarks

The study has evidenced a significant beach loss along the Maspalomas beach during the investigated time interval and an elevated shoreline dynamic that has affected the study beaches especially during the last decades. With reference to most recent shoreline changes, analysed data suggest the need to investigate about causal aspects by means of a detailed analysis of the wind regime and the related longshore sediment transport, on one hand, and the role of hard protection structures that have deeply influenced local shoreline dynamics and sediment trapping, on the other hand. Furthermore, the prevailing negative shoreline trends of the easternmost beaches during the latest period 2010-2016 may highlight the possible role of increased wave dynamics, affecting mainly the eastern sector of the study area.

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The vulnerability of the coastal archaeological sites located along the Posillipo Hill (Gulf of Naples, Italy)

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Introduction

Along the coasts of the Mediterranean Sea, many ports and protection structures have been emplaced since the Greek and Roman ages and have persisted until present days. Most of such ancient coastal settlements are today submerged providing useful indicators of sea level changes and coastal landscape evolution over the last 2.500 years (Morhange and Marriner, 2015). They also represent an inestimable cultural heritage often threaten by coastal erosion and/or flooding processes. The aim of this work is the vulnerability evaluation to marine processes of five archaeological sites located in the Gulf of Naples, along the Posillipo Hill. In order to provide a vulnerability level of each of the investigated sites, a new specific index-based method has been improved. . The method is based on a number of variables related by means of matrices as widely used in literature for the evaluation of the coastal vulnerability (Gornitz et al., 1994; Rangel-Buitrago and Anfuso 2015; Mysiak et al., 2018; Rizzo et al., 2018, among others).The results obtained allow to state that this index approach is a useful method allowing to obtain a first level of assessment of the proneness of the archaeo-sites to be negative affected by marine processes. In accordance with the purpose of the International Council on Monuments and Sites (ICOMOS), which represents the advisory body to the UNESCO Commission for all aspects concerning cultural heritage, this study aims to contribute in improving the preservation and conservation of relevant cultural heritage places.

Study area

The Gulf of Naples was used as a case study given that it is an outstanding example of the continue interplay between coastal changes (due to aforementioned geological processes) and human adaptations, as this area was densely inhabited since Greek times (Aucelli et al., 2017a).
The study area is the Posillipo hill, on the southeast border of CF volcanic area, an asymmetrical and homoclinal structure mainly made of Neapolitan Yellow Tuff (15 ky, Deino et al., 2004). This coastal sector hosts the remains of the luxury Roman villa known as the Pausilypon villa, built in 15 BC by Publius Vedius Pollio and renovated during the Augustan age. The Pausilypon villa was built on various terraces sloping down toward the sea and included coastal buildings and structures as the so-called Palazzo degli Spiriti of Nisida and Marechiaro harbors. Due to the subsiding trend affecting this coastal sector (Aucelli et al., 2017b and 2018), all these structures are semi or totally submerged. In this study, the five main coastal structures annexes to the villa were analyzed in order to evaluate their vulnerability to the present coastal processes.

Materials and Methods

The analysis is supported by the definition of specific matrixes that allow estimating the vulnerability level of the coastal archaeological sites to marine agents, accounting for the type of structure and its position along the coastal sector. In detail, depending on the potential robustness and resistance to dynamic processes, five types of structures have been defined: i) Maritime structures; ii) Vertical narrow structures; iii) Vertical wide structures; iv) Horizontal structures; v) Collapsed structures. Furthermore, depending on the coastal position (backshore, foreshore, nearshore and offshore zone), different processes linked to aeolian and marine agents can potentially impact the archaeological sites. For this reason, a specific vulnerability matrix is defined for each coastal zone by combining coastal processes and archaeological structure typology. A **Vulnerability Value** is then assigned to each structure based on the specific potential effect of each coastal process: from 1 (low) to 3 (high impact on the structure). Last, a **Vulnerability Weight** is assigned in relation to the frequency of occurrence and importance that the process has in each coastal zone. Therefore, the overall **Vulnerability Index (VIn)** of each structure varies with respect to the beach zone in which the structure is located, as it derives from the sum of the effects of coastal processes acting in that zone. **VIn** values, calculated by means of a weighted average, range between 0.1 and 3 and are finally classified in three vulnerability classes: 0.1 – 1 (Low Vulnerability), 1.1 – 2 (Medium Vulnerability), 2.1 – 3 (High Vulnerability).
In case of the presence of physical protection structures (such as jetties, groins, breakwaters, etc.), the **VIn** value is multiplied by a Correction Factor (CF) equal to 0.5.

Results and Discussion

Results obtained by applying the proposed method to archaeological sites located in the Gulf of Naples are synthetized in Figure 1. The first site studied is the Nisida harbour, whose remains are now testified by two pilae making up the ancient pier. The pilae are totally submerged and lay on a tuffaceous sea-bottom at a depth of -9 m asl, in the offshore zone. These structures belong to the Maritime structures category and have a VIn value equal to 0.8. The well-preserved conditions of this archeological structure are in agreement with the low vulnerability class associated with it.

The second studied site is the fish tank related to the main part of the Pausilypon villa. This beautiful maritime structure, with its walls made in concrete, is one of the best-preserved fish tanks in the Mediterranean. The structure lays at a depth of -4 m asl, in the nearshore zone and belongs to the medium vulnerability class (VIn value: 1.4). In fact, this site is included in the area A of the underwater archaeological park of Gaiola, and hence it is continuously monitored and protected.

Palazzo degli Spiriti, the third archaeological studied site, is the best-preserved building along the Posillipo hill, built in the 1st century BC with traces of renovations during the period of use. Presently, the ground floor is at a depth of -2.4 m asl and the various rooms of the two levels are still visible. This site, lying in the nearshore zone, has a VIn of 2.1, then belong to the high vulnerability class. In fact, as several historical photos demonstrate, this site is being destroyed mainly due to wave action.

Inside the Marechiaro bay, the remains of a small villa (the so called Pollio villa) are protected by a breakwater. The foundation of this building stays in the nearshore sector and, due to its shape, belong to the Vertical wide structures category. Then, a medium vulnerability class (VIn value: 1.1) is associated with this site. In fact, thanks to the presence of a physical protection a correction value of 0.5 was applied to the vulnerability index.

The last archaeological site considered was that off Capo Posillipo. On an ancient coastal plain emerged during the 1st century BC and protected by a breakwater 195 m long, there are the remains of three small villas. Both the coastal plain, the breakwater and the villas foundation are nowadays submerged. This site, located in the nearshore zone, belongs to the category of Vertical wide structures and is protected by the ancient breakwater. Also in this case the site belongs to the medium vulnerability class. In fact, even if the site is located in the most exposed part of Posillipo cape, the foundations of the villas are still visible.

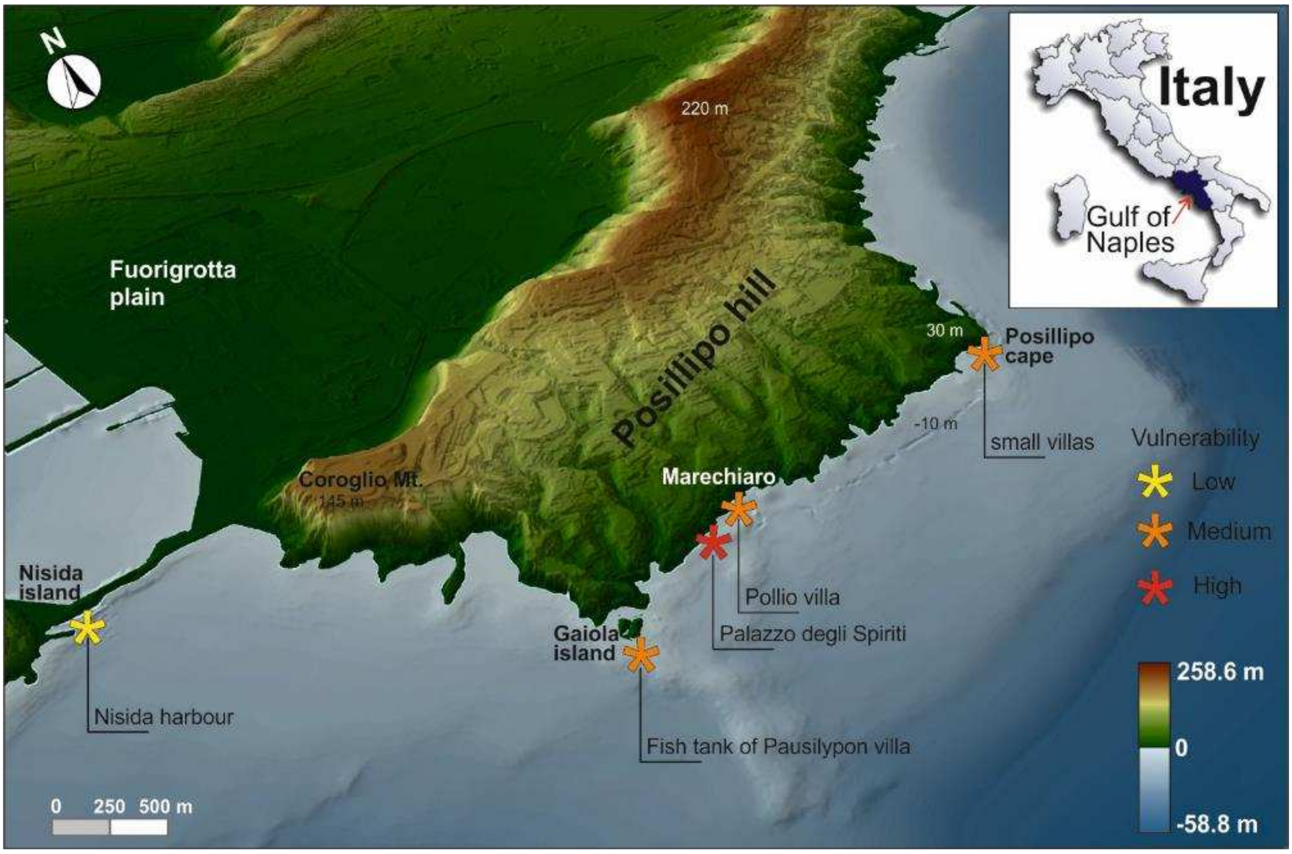

Figure 1: Vulnerability assessment of the archaeological sites located in the Gulf of Naples (yellow: low vulnerability class; orange: medium vulnerability class; red: high vulnerability class).

Conclusions

This study represents a first attempt aimed at the assessment of the vulnerability of the coastal archaeological sites located along the Posillipo Hill. The investigated sites are characterized by a notable cultural, environmental and social value, representing part of the most important cultural heritage of the entire city of Naples. The analysis here proposed allowed to identify among the five sites the ones that have higher vulnerability values and require therefore priority actions for their conservation. In particular, Palazzo degli Spiriti was the most vulnerable one to coastal processes and, furthermore, not covered by legal protections because it was located on the outer limit of the Gaiola archaeological park.

In conclusion, the index-based approach has resulted to be an effective and easy to apply tool for supporting the protection and the preservation of archaeological heritage sites specifically located along coastal sectors. Further investigation will be focused in the first instance on the adjacent areas in the Gulf of Naples, and afterward in other Mediterranean coastal sectors with high cultural value.

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New defense of the natural nourrishment and seabed grassland

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New defense location is in the seabed transition zone between enormous offshore pulsing vertical waves energy and conversion into inshore horizontal currents energy.
Artificial reef, articulated in staggered barriers of the turbines, compose a soft defense of the coasts that mimics the coral reef, especially for its location far from the storms.
The barriers reduce the sea currents speed below the sea level with the consequent deposition of the suspended sand for natural nourishment.
The patented vertical turbines are made up of helix fixed to a floating spinning top so as to be in indifferent equilibrium in water, for which they turn by the minimum currents.
The electric energy is produced even at low number of laps, but long lasting and therefore with hours of production higher than the eolic and photovoltaic.
The costs of these barriers are very advantageous compared to the actual coastal defenses, based on the nourishment and on the cliffs, because the direct electrical dispatching covers the cost of amortization, and specially the cost of the maintenance.
The new defense, in order to prevent sea level rise due to climate change, also embank the coast flooding through the natural nourishment and re-growth of the marine grasslands, so as recovering hectares of the beaches, with great economic benefits.
The reconversion of the usual nourishment and the cliffs by proposed energized reef recoveries the marine ecosystem, the landscape and promotes the sea depollution.

Keywords: erosion-flooding defense, marine energy converter, floating turbines reef

1. Introduction

The Organization of Cultural Volunteering STES, Scientists and Technologists for Development Ethics, which for thirty years has been trying to document and disseminate good practices, especially for the protection of human beings and the environment.
Since some years STES signaled the urgency of formulating proposals and carry out research concerning the defense of coastes.
If we want also to try to reach a 50% reduction of the current 80 billion tons/year of global CO_2 emissions in 2050, it is essential to support the realistic increase in renewable energy, beyond hydroelectric power, from the current 4 % at least 30% (EU sets at 32% in 2030).
Related to this subject, a valid contribution comes from marine energy, especially when combined with the defense of the eroded coastlines, which since always is based on cliffs and nourishement, in an anti-ecological and anti-economic way.

2. Description of the new defense

The idea starts from the observation that the energy of the wind produces enormous pulsing vertical waves on the sea (J. Boussinesq 1897), when the bathymetry is deep; then, approaching the coast, where the seabed is around6 ÷ 7 m, the same waves (fig 1) are converted into direct horizontal currents towards the shore (G. Ferro, 1970).
This occurs, according to slope marine geomorphology (J. Mas-Pla, G. M. Zuppi, 2009), about 300÷ 500 meters on average from the shore, when the currents then proceeding on lower bottoms, 3 ÷ 4 meters, they are converted into storms, which causes erosion.
After the offshore/inshore calm area there is the *inshore mature formation of horizontal currents*.
In this particular zone a new artificial reef can be placed as soft defense, that mimics the coral reef, especially for its *location far from the storms*.
The traditional defenses of the coasts are based on artificial nourishment (fig. 2) often made with withdrawals offshore fine sediments, systematically removed from the storms, and are based on cliffs near the beaches (fig. 3) that induce upheavals of the seabed and erosion of the unprotected beaches, so these types of defenses are inefficient and expensive.
To help modify these traditional types of defenses, a new energized reef is proposed.

The patented vertical axis turbines (fig. 4) are constituted by propellers fixed immediately below the sea level between two floats: the superior disc is for lamination of the currents and the inferior disc is a whirligig for the spin stabilization. The turbine is in indifferent equilibrium in water and then turn at the minimum marine currents, in this zone the electric energy is produced even at low number of laps but long lasting, with hours of production higher than the eolic and photovoltaic.
The tubes on which are pivoted the propellers, are implanted in the sand like shells of the "sea razor clams" and are made of fiber-reinforced recycled composite materials, already on the market for offshore structures.
The floats-crankshaft-propeller block is realized with the same material by 3D printers, and drives a low-frequency multipolar dynamo.
The turbine, nearly 20 kW, converts marine energy starting from 2 ÷ 3 kW/m of the waves energy.
Furthermore, the hours of electricity production are much higher than wind, as the water pushes much more than the air on the propellers, and they are more efficient than photovoltaics, since the marine turbines can work even at night.

The tubes are vibro-infixed at a suitable depth of foundation in the seabed, similar to the mooring dolphings (P. Ventura 2019), so as to constitute strong prefabricated tripods module, bonded at the base by a triangular mesh.
These fixed pipes, to keep stable the propeller disposition, can be replaced by foundation consisting in a continuous truss placed on seabed, anchored like boats, adaptable to marine displacements.
This submerged foundation assimilates the impact to that of a naval wreck, and increases the diver tourism.
The truss on seabed also allows the transportability for defense of other litorals, after the ecosystem stabilization especially by regrowth of the poseidonia.
The arrangement of the turbines, staggered in the barriers, allows a sensitive damping of marine currents in order to reduce the speed and create a "soft" defense of the coasts without collateral effects.
The planimetric distribution of the turbines must be adapted to each shoreline (F. R. Lucchi 1992) based on the geomorphology of the seabed and the fecth maritime weather data that both characterizes the energy of the waves that goes from over 10 kW/m in Sardinia to less than 5 kW/m on the coasts of Tirreno.

The new reef defense allows to raise the level of the beach through the natural nourishment, in order to guard the rising sea level caused by climate change and impressive melting of the glaciers (3 mm/year).
The flooding of the beaches, nearly 1m/10 years (slope 3 cm/m) is dammed with the proposed defense, especially where the solid transport of the rivers is low.
In Italy, erosion affects over 1200 km of coastline, equal to 1/3 of the beaches, that have also been reduced by 25 m, or more than 2 ha/km.

The barriers allow further advantages concerning the rooting of sea grasslands, especially of posidonia, which prevent erosion and promote fish repopulation and sea de-pollution, also preventing eutrophication, instead favored by the cliffs next to the beaches.
In particular, the boulders of the cliffs could be transformed into gravel of suitable granulometry by integrating the barriers to protect the coastline and avoiding the extraction of sand both at sea and on land, due to significant environmental damage, with restoration of the original landscape.
The turbine reef, leaving the suitable passages to boats, places a limit on fishing and recreational navigation, bringing it to regulatory distances in favor of safety.
The along turbines reef allows mooring of the boats, not clogging the ports, and energy production recharging even the accumulators, in particular the boat owners could buy turbines.
You can also feed a series of the marine vacuum cleaners (seabins), especially to free the sea from finely shredded plastic and other garbage; and also the sensors for chemical control, with safe water quality from "blue flags".

Moreover the turbines, having the same specific gravity of the water, have a period of null oscillation that escapes resonance and are therefore earthquake-resistant so they also work in the event of an earthquake emergency; submarine cables are then damaged by the bad weather in a way less than the terrestrial ones.
The proximity of the coasts to the Apennines allows the hydraulic storage of renewable energy by pumping water at high altitude with "reverse" pumps-turbines, in order to balance the uncertainty of current production and contribute to mitigate the release of CO_2 into the atmosphere, and the fuel particulate (HC, NOX, CO, PM).

3. Economic competitiveness of the coasts defense by turbines reef

The wind power currently installed in Italy is about to reach 10 GW, the valid contribution is done by described marine energy production, specially coupled with defense of the coasts.
The investment of 1 km of coastline varies from 100 to 200 turbines reef, with duplication of energy production; can also be foreseen a integration by economic static profiles.
The production from 5 ÷ 10 GWh/km per year depends on the exploitable marine energy and extension of the propellers. This production of electricity supports the maintenance, amortization, public lighting and domestic utilities of coastal Municipalities, also via direct dispatching.
The duration, at least 20 years, involves a very favorable economic recovery of the beach with the average sizes of 1ha/km for bathing.

This life of the turbines reef allows the re-growth of the prairies and the restoration of the marine ecosystem, currently unfeasible, also does not produce waste (circular economy) being the recyclable floats for the production of new turbines or transferable with a tug to defend other shorelines; in any case the barrier defense function, even if not energized, remains.
The current cost of construction of the actual cliffs and nourishment is higher, especially considering that the seasonal maintenance exceeds considerably one million €/km/year without any advantage.
This especially if the beach is restored with fine sediments, which are quickly removed from winter storms, with exponential costs. The turbines reef therefore become economically decisively competitive in the reconversion of the current traditional defenses, especially for annual maintenance, with public spending review and management of bathing establishments proportionate to the hectares of beaches recovered and redeveloped.
The progressive fossil / renewable transition is favored by these energy barriers, especially if proposed in place of nourishment and cliffs. In addition, the turbines, coupled with trimmers, can also be used with fluvial currents.

The advantages highlighted are such that it is particularly convenient to support the financing for a gradual experimental research, articulated in the collection of data on marine currents, fluid dynamics simulation, and real experimentation on a group of turbine prototypes.
Moreover, the experimentation should be focused on the extension and shape of the propeller blades to be calibrated as a function of the erosion energy to be damped on a case-by-case basis according to the chosen site.
It should be noted that the financing in Europe and in China concerning the production of marine energy (WEC Wave Energy Converter) is in full development: it is important to promote Italian Research with Horizon2020 funds, especially to promote Benefit Corporation based on the profit / noprofit synergy.

4. Advantages of the new coasts defense

- Soft defense of the erosion due to the serious anthropizations and climate change, **without strong side effects.**
- Marine energy production for reef **maintenance, amortization and direct dispatching**.
- Turbine location after calm due to offshore / inshore processing and **away from sea storms, in order to reduce maintenance costs.**
- Floating indifferent turbines, turning to the minimum currents, are **more efficient than eolic**.
- The turbines barriers reduce the sea currents speed with **deposition of the suspended sand.**
- The levels of the beaches and the banks of the river deltas banks are increased **to prevent the flooding caused by rising sea.**
- **Great economic benefits and landscape retraining** through the recovering hectares of beaches.
- **Reconversion of the artificial nourishment and cliffs** by turbines reef.
- **Significant reduction in public spending** on coastal defense maintenance.
- **The barriers allow the engraftment of marine grasslands** that prevent erosion.
- **The prefabricated reef are realized by recycled fiber-reinforced** material by 3D printer.
- **Operating life of the energized reef, about 20 years, is regenerable** in new defense also static.
- **The reef is also transferable in other seabed** after regrowth of the posidonia, to the stabilization of the seabed.
- **Reverse-turbines allow hydraulic storage** of renewable energy by pumping water at high places.
- **Public lighting and the domestic utilities** of the coastal Municipalities increase the security.
- **The emerged cliffs elimination** avoids eutrophication and promoting the seabed decontamination.

- **The barrier is equipped with seabins to clean the garbage** and also the sensors for chemical control, with safe water quality from "blue flags".
- **The crushing of the cliffs boulders** allows a suitable nourishment and landscape retraining.
- **The barriers limit to recreational navigation**, bringing it to a safe distance.
- **The turbines could be purchased by boat owners and prosumer** or feed charging columns.
- **Turbines are also operational during the earthquake**, the indifferent relative mass to the water escapes the resonance.
- **Turbines can also be used in rivers** protected by rakes.
- **Contribution at the transition** fossils/renewables energy, and to new defenses of the coasts.

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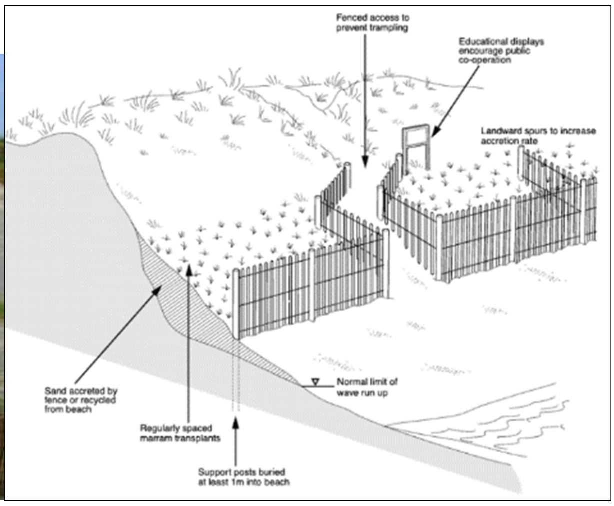
Soil bioengineering in the Mediterranean coastal environment

Nicola CANTASANO (ISAFOM Cosenza) - Federico BOCCALARO (AIPIN Lazio, Roma)

Introduction

Soil Bioengineering is a part–discipline of civil engineering. It pursues technological, ecological economic as well as design goals and seeks to achieve these primarily by making use of living materials, i.e. seeds, plants, parts of plants and plant communities, and employing them in near-natural constructions while exploiting the manifold abilities inherent in plants.
Bioengineering may sometimes be a substitute for classical engineering works. However, in most cases it is a meaningful and necessary method of complementing the latter.
Its application suggests itself in all fields of soil and hydraulic engineering, especially for slope, embankment and coast stabilization, and erosion control.
Soil Bioengineering techniques have been important in ancient Mediterranean civilizations: plants have effectively protected the soil and necessary materials (plants, timbers and stone) have abounded in agrarian landscape, often in combination with terracing.
Recently, this discipline has spread to several areas of the Mediterranean ecoregion. Various methods and plant species have been experimented in territories with different climate and vegetation than the original Alpine one.
Soil Bioengineering techniques have been frequently applied in Italy, particularly in Vesuvius, Latium, Abruzzo and Marchigian Apennines, Sicily and in various Coastal and Marine Protected Areas, also through experimentation, didactic and voluntary actions.
In the context of Soil Bioengineering projects in the Mediterranean ecoregion, these systems have shown that xerophilic plants and cuttings use is reliable for droughty, desertified and burned environments.
Soil Bioengineering, increasingly widely in the Mediterranean, reaches the objectives of:
• protecting against natural hazards;
• restoring habitats;
• defining the best species for their radical architecture;
• sharing and diffusing the interventions.
Unstable dune surfaces are subject to erosion and provide a source of sand which may blow and smother adjacent areas.

In a coastal environment, stabilisation may be needed to:
- Prevent the loss or deterioration of valuable natural habitat
- Maintain dune ridges which act as coastal protection for low-lying hinterland
- Protect backdunes development of agricultural or recreational dune grasslands
- Allow maintained or increased levels of public use
- Allow the afforestation of backdunes and stabilised dune ridges.



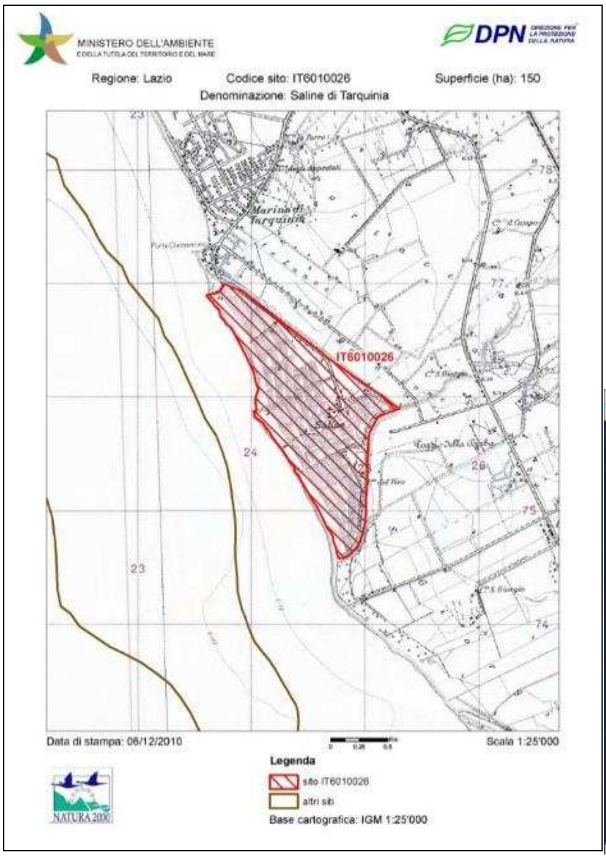
Protectionist – environmental aspects in a Natural Reserve

The State Natural Reserve "Saline di Tarquinia", although from an environmental point of view the value of a saltwater lagoon behind the dunes, is an artificial structure built for productive purposes which now only has ecological significance: it is in fact part of the Natura 2000 network, being both an ZPS that an SIC under the Habitats and Birds Directives. The salt mining has, in fact, gradually reduced over time due to its uneconomical and it is totally ceased in 1997.

The water balance is still kept artificially ponds to pumping seawater into the tanks: the latter are separated from the sea by a narrow coastal dune while a surrounding drainage ditch, built in 1800 to cut the fresh water blade that reached the tanks, marks the boundary between the saline and the surrounding land. The Salt Pans reservoirs represent a particular ecosystem brackish due to the salinity gradient that distinguishes them.

In addition to the ponds the Reserve includes a variety of environments such as beach, dune, mediterranean machair, grassland and pine forest. The coastal dune is highly subject to sea erosion that is gradually decreasing it, and that, in the medium-term future, represents the most serious threat to the conservation of salt pans ecosystem.

The seabed in front is characterized by the presence of Posidonia meadows mainly on hard surfaces. It is detectable in a strong degradation of the grasslands essentially caused by the alteration of river regimes due to the presence of branch canals and irrigation, resulting in sediment transport alteration. This increased the turbidity of coastal marine waters, preventing Posidonia meadows photosynthesis.



Educational-experimental intervention of Coastal Bioengineering

The staff of the State Forestry Department of the UTB of Rome, together with experienced members of the AIPIN (Italian Association for Naturalistic Engineering) - Lazio Section, with the sponsorship of the TCI (Italian Touring Club) - Volunteers for the Cultural Heritage of Rome, have been available to support the activities of the "Sister Water" educational project, both through interventions in the classroom, and through visits and practices in natural environments.

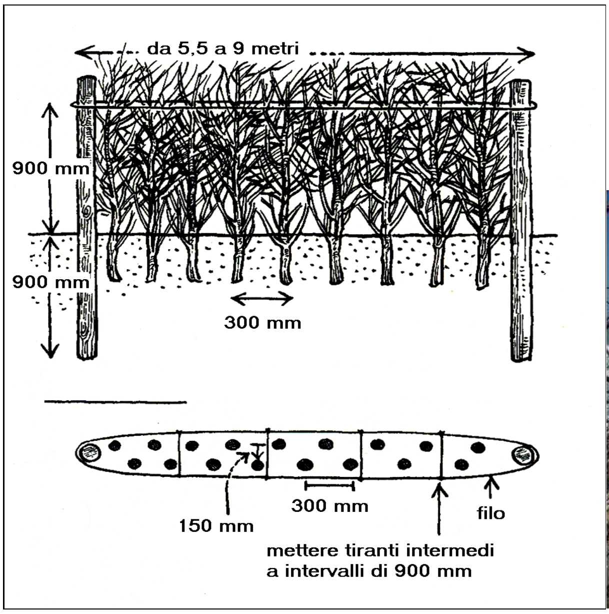
The educational sites for the spring 2016 - 2018, directed by the AIPIN expert partner Federico Boccalaro, covered short stretches of fore dune ridge, one of the most exposed to sea erosion, beyond the Reserve fence, parallel to the shore line. The interventions carried out along the low dune ridge were, proceeding from the inland sea:

• wave barrier in chestnut timber “soldiers”, filled with brushwood, to defend against storms;
• protective belt in jute-sand bags close to the barrier, to defend against storms;
• "brushwood and stake" fencing, "dutch" fencing and "post and wire with brushwood” fencing, using chestnut posts, steel wire, brushwood and common reeds, for trapping sand;
• planting psammophile plants transplanted from the wild, to restoring dunes to their original state.

There are two basic types of post and wire fence used on sand dunes:

- Strained wire fences. These fences are usually over 10m in length, and are used either for access control, or to support synthetic netting for trapping sand. The fence has a straining post at either end, which takes the strain of the wire. The intermediate posts strengthen and stiffen the fence, and hold the wires at the correct height. When constructing the fence, wire strainers such as “Monkey” strainers are used at the straining post to pull the wire tight. Either mild steel wire or high tensile steel wire can be used, the latter requiring stronger straining posts. The wire is fastened off at the straining posts, but at the intermediates is held by a staple driven far enough to just touch, but not grip the wire.
- Non-strained wire fences. These are short lengths of wire and brushwood or chestnut paling fence. No straining posts are built, so the wire cannot be tightly strained but is merely tensioned by hand, and fastened to each post with a staple which grips the wire (though does not distort it). The strain is thus held equally at each post. Monkey strainers are not used. The posts are normally spaced closer together than are the intermediate posts of strained fences.

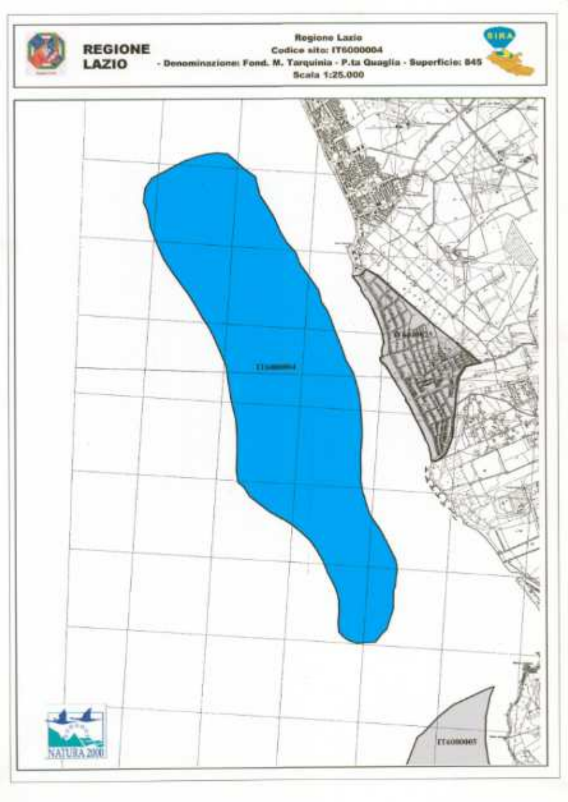
These are low-cost soil bioengineering techniques of great naturalistic value, which are commonly used along the coasts in Northern Europe, especially in the Netherlands, but which are still new in Italy: these methods are based on a high level professionalism and the availability of motivated volunteers, as well as a continuous monitoring and maintenance system, aimed at restoring more or less serious damage that wind, storms and vandalism will inevitably produce on the natural materials used.
The very nature of the problem means that fencing material cannot last many years, and normal wave action and the occasional storm will damage or completely remove the fencing.
When erecting fencing primarily as wave barriers, which are unlikely to be permanently buried by sand, it is important to consider what maintenance is likely to be needed to keep it effective, and who will undertake this. This type of work is a constant battle, and constant maintenance with some replacement of materials is likely to be needed.



Posidonia oceanica meadows reforestation project

Specific priority objective of conservation and management of the SIC site "Seabed between Marina di Tarquinia and Punta Quaglia" is to ensure the maintenance or restoration, in a satisfactory state of conservation, of its habitats and community interest species, with high or medium conservation priority.

A further conservation and site management objective is to guarantee or improve the conservation status of present habitats and community interest species, identified as low conservation priority, also promoting conservation of other fauna and flora important present species.
The replanting of Posidonia oceanica techniques developed to date are numerous: the most used include laying of concrete frames, containing a metal grid, on which are fixed the cuttings of *P. oceanica*, and placing metal or plastic grids on the seabed, on which are fixed the cuttings. Although the restoration of seagrass *P. oceanica* has shown encouraging results to date, difficulty of anchoring cuttings, used for replanting, on the seabed remains a major limiting factor for the success.
A reforestation and protection project was planned for *Posidonia oceanica* meadows with methods already experimented in the Tuscan Archipelago National Park, in the locality of Cavo, Elba Island (LI), in the AMP "Capo Rizzuto", Sovereto (KR), and in the AMP “Capo Carbonara”, Villasimius (CA), using “Soil and River Bioengineering" materials.
The materials used are of different nature: vegetated gabion mats, double twisted galvanized steel wire mesh, organic or synthetic mattresses. Finally, to verify the possibility of using a fully biodegradable material in areas of particular environmental value, will be experienced in the use of coconut or agave geotextiles.
The last results seem to indicate that the materials chosen can be advantageously used in reforestation work with *Posidonia oceanica* and other seagrasses, due to their high stability and resistance to hydrodynamic phenomena and to erosive actions caused by currents and waves, the simplicity of assembling and positioning in the sea, the possibility of pre-packaging ashore (with considerable savings in underwater activities) and to substantially low costs of realization.
The results of future experiments could be encouraging, showing the possibility of extending to marine environment many of the methods commonly used by “Soil Bioengineering" for the erosive defense of terrestrial and fluvial environment.



Importance of coastal bioengineering interventions

The intervention from the hydrogeological and naturalistic point of view has to:
- guarantee an adequate hydrogeological defense of the coast in a singular point, for the prevention of further hydrogeological instabilities;
- avoid a further impact factor, in order not to compromise the quality of the local habitat;
- be in harmony with the surrounding environment, through the adoption of specific Bioengineering techniques, as well as elements and forms typical of the area;
- allow the theoretical and preliminary training of student, forestry and specialized volunteer staff.

Extreme events in Venice and in the North Adriatic sea: 28-29 October 2018

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KEYWORDS
- *Storm surge*
- *Sea Level Forecast*
- *GPD (Generalized Pareto Distribution), GEV (Generalized Extreme Values)*
- *Venice and the North Adriatic Sea*
- *Floods Directive (2007/60/EC)*

Introduction
Sea level variation and prediction have always been very challenging issues aimed at protecting and improving the marine environment, especially in the North Adriatic Sea and in the Venice Lagoon, that are increasingly exposed to the flooding risk from storm surges, well known as *acqua alta* phenomenon.
In the last century the city of Venice has seen an increase in the frequency and intensity of the flooding events that periodically submerge parts of the old city centre; during the 28-29 of October 2018 Venice and the North Adriatic in particular, have been exposed to a marine extreme event due to severe weather conditions [3].
This event was characterized by a very low atmospheric pressure structure incoming on the west Mediterranean Sea. A strong and persistent south-east wind (*Scirocco*) flowing on the Adriatic Sea caused rainstorms on the Alps and very high and rare coastal storm surges reaching unexpected extreme values. Different and dangerous consequences of this event had to be faced as concerning the coastal risk as well as the hydrogeological one, so much that the Italian Civil Protection Department emitted the national environmental alert.
These floodings pose a threat not only to the artistic, cultural and environmental heritage, but also to the economic assets. To be able to face these floodings and to manage their occurrence, it has been invested in the safeguarding of Venice through the planning and building of flood barriers, many other structural measures as well as through forecasting operational systems, measurement networks and extreme events research activities.

Data and method
In this work it will be described the weather situation that led to the considered storm surge event and the sea level operational forecasting system developed by ISPRA. Moreover, in order to deal with extreme events and to characterize their rareness, a deep investigation of the longest time series recorded in Venice have been applied, pointing out information referred to return periods and return levels.

Observed data
Measured data have been used as for the feeding of the integrated operational system as well as for the analysis of sea level extreme events phenomena; in this work data provided by tide gauges belonging to the ISPRA Sea Level Measurement Networks (RMN and RMLV) have been considered.
It has been analysed, first of all, the meteorological data related to the atmospheric pressure and the wind intensity and it could be easily highlighted a very high Scirocco wind speed (20-24 m/s) on the 29th October 2018 (yellow circle in figure 1) due to the high atmospheric pressure difference between the southern and northern Adriatic Sea. The strong wind coming from south-east and the low pressure in the north Adriatic have been responsible for the sea level growth as confirmed by measured data (figure 2). The red line shows the meteorological contribution (residual) as the difference between observed and astronomical sea level: the highest values were reached on the 29th October during the maximum wind intensity and fortunately at the minimum astronomical tide. The peak recorded at Venice city centre was 156 cm as referred to the Zero Tide Level at Punta della Salute (Italian acronym: ZMPS); this value is the fifth highest case of the time series starting from 1872 and about the 70% of the historical city centre was flooded for more than two hours.

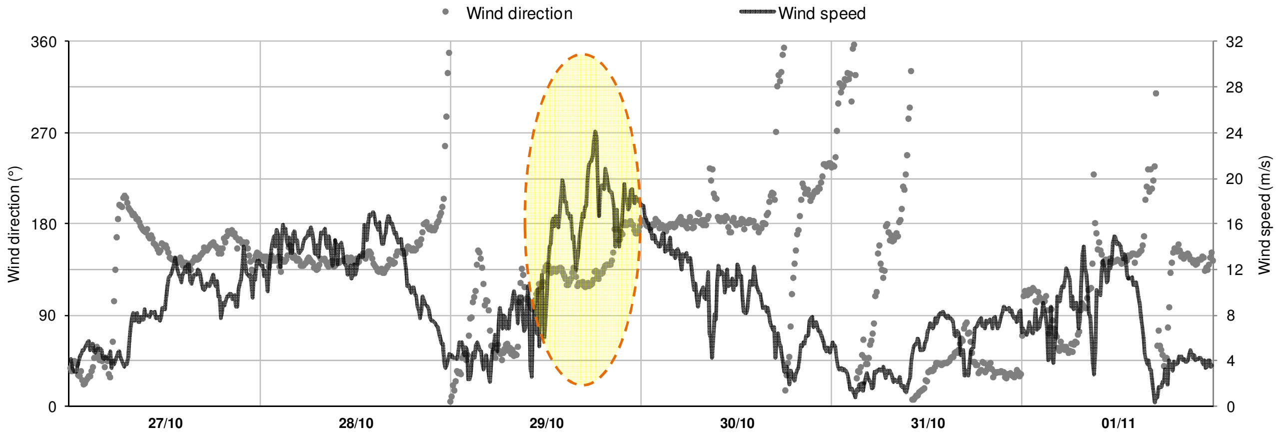

Figure 1. Measured wind data at CNR platform, station located at 15 km offshore the venetian coast.

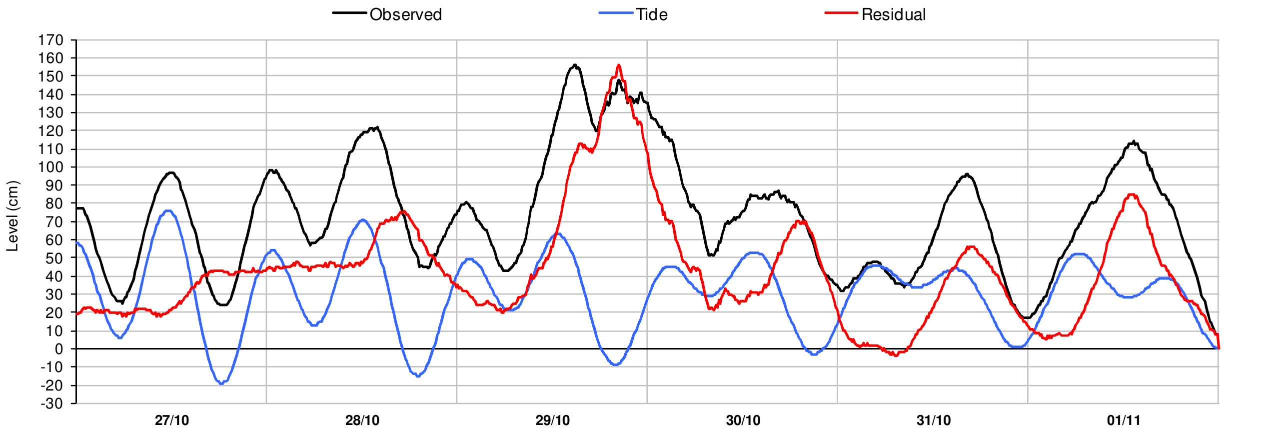

Figure 2. Measured water level, astronomical tide and residual at Punta della Salute.

Storm surge forecasting system

ISPRA developed an integrated operational forecasting system consisting in two different models, a numerical one and a statistical one, in order to predict dangerous events and to manage their occurrence. In this work it has been considered the numerical model results, since they showed more reliability with respect to the statistical one during the extremely high tide events.

The numerical model SHYFEM, developed at ISMAR-CNR ([1], [2], [9], [10]) is a hydrodynamic model based on finite element method and used to compute the storm surge contribution in the Mediterranean Sea, especially in the Adriatic Sea and in the Venice Lagoon, under the action of atmospheric forcing fields. The meteorological inputs (pressure and winds) are operationally provided by the European Centre for Medium-Range Weather Forecast (ECMWF) and by a limited area meteorological model (BOLAM) developed at ISPRA for the hydro-meteo-marine forecasting system (http://www.isprambiente.gov.it/pre_meteo/).

The meteorological forcings cover the Mediterranean area with different spatial and time resolutions: the ECMWF atmospheric fields are supplied at synoptic hour (00, 06, 12, 18 UTC), they have a spatial resolution of 50 km both in latitude and longitude and the forecasting period is 96 hours. The BOLAM meteorological fields have a higher space (11 km both in latitude and longitude) and time (data frequency is one hour) resolution; the forecasting period is 84 hours. The numerical model forecasts the sea level elevation with resolutions ranging from 40 Km in the Mediterranean Sea, 2 Km in the Adriatic Sea and reaching about 100 m in the Venice lagoon.

A data assimilation module based on the 4-D Physical Space Assimilation System was developed for integrating the residual sea level measurements from the tide-gauges of the ISPRA observation network located alongside the Italian Adriatic coastline [2].

The operational system produces therefore eight runs per day for all the locations of interest in the Venice Lagoon (Punta della Salute, Burano, Chioggia Vigo) and in the northern Adriatic Sea (Lido Diga Sud, Grado, Porto Caleri), available at www.venezia.isprambiente.it.

Extreme events analysis

Peak Over Threshold Method and Generalized Pareto Distribution (POT-GPD)

The Generalized Pareto Distribution model could be fitted for the observed extreme data with considering the following assumptions: data are considered as exceedances from a specific threshold, which are a sequence of independent and identically distributed measurements. In order to achieve these assumptions the Peak Over threshold approach has been applied. It provides a model for independent exceedances over a high threshold. In this method the threshold needs to be neither too high (to get enough observations) nor too low (not to take into account non-extreme values) and just maxima separated by 78 hours below the threshold have been chosen, in order to ensure extreme independence [8]. Once declustered maxima, the Generalized Pareto Distribution can be fitted [7] using a maximum likelihood estimation of the distribution parameters such as the scale parameter, the shape parameters (that gives information on qualitative behaviour of the distribution) and the location one. Finally it has been possible to evaluate return period and the related return level ranging from 1 to 100 years (table 2).

Generalized Extreme Values (GEV)

The Generalized Extreme Values model could be fitted for the annual maxima and it is specified by two parameters: the scale parameters and the shape one similarly to the GPD approach. Depending on the shape parameters it could be obtained a Gumbel, a Frechet or a Weibull [5]. The limit of this approach is that using annual maxima it reduces the amount of extreme measurements to be fitted. However also in this case it has been possible to evaluate return period and the related return level ranging from 1 to 100 years (table 2).

Results

In order to fully understand what happened during the 28-29 of October event, a deep analysis of sea level forecasted and measured data have been applied.

In figure 3 the observed and forecasted sea level data at Punta della Salute are compared: the brown area represents the water level forecasting range obtained taking into account at each time the minimum and the maximum value of all the eight forecasting curves. The wider the range is, the more different the predicted levels are. Moving from the top to the bottom of the figure 3, are presented the 72h, 48h and 24h before the *acqua alta* event sea level forecasts. It could be highlighted that all models underestimate the real values 72h in advance, a good forecast for the peak of 156 cm 48h in advance, and a good prediction also for the second peak 24h in advance.

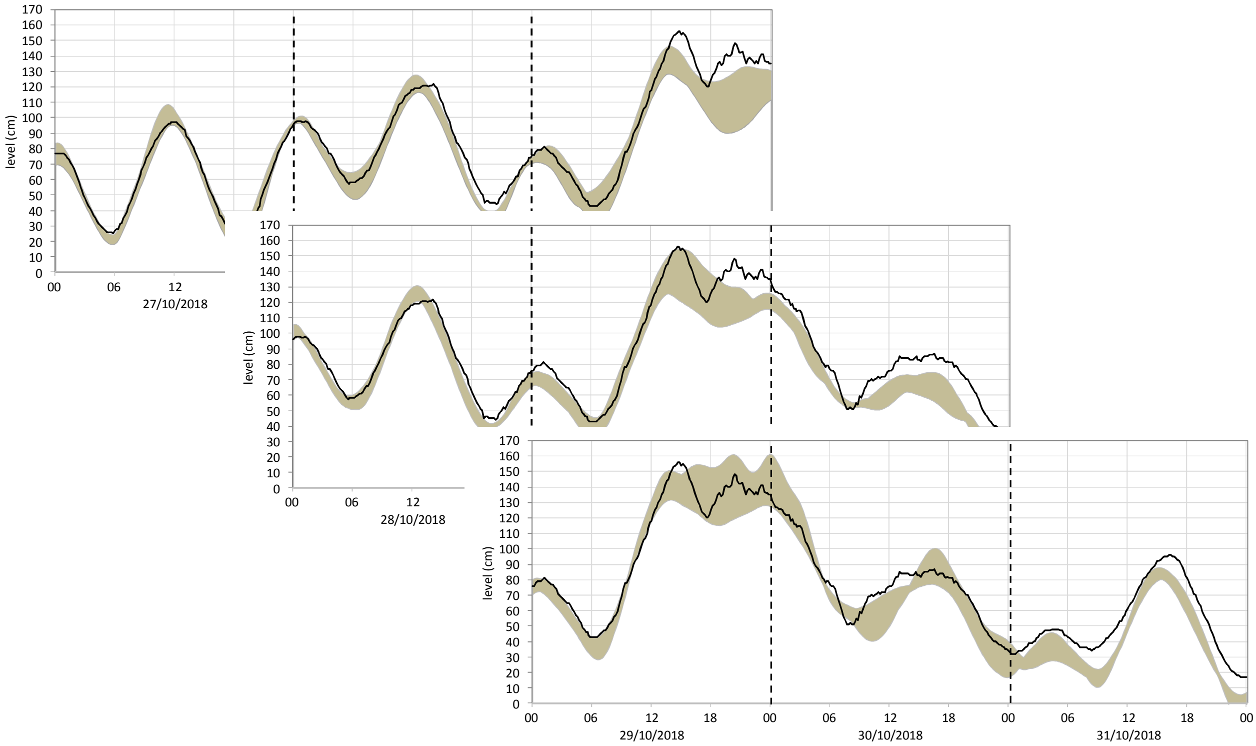

Figure 3. Punta della Salute water level observed (black line) and predicted on the 27th (top), 28th (middle) and 29th (bottom) of October. The brown area is the min-max range calculated with all daily model runs.

To evaluate the model performance, the mean error and the RMSE for each forecast lag (72, 48, 24 hours) were calculated. The analysis was focused on the 29th of October, and the mean error at different forecast lag for the eight model runs calculated. The models forced by the BOLAM meteo fields show a better performance with respect to the results obtained with the ECMWF forcings; the errors indicate a underestimation of the real water level 48h and 72h in advance and an overestimation in the last forecast (24h). Otherwise, the ECMWF forced models underestimate the surge at each forecast lag but the mean errors considerably decrease approaching the extreme event.
The obtained results were compared with the ones calculated using the predicted values for all the events higher than 120 cm in the period October 2012 - September 2013 [4]; even if values higher than 150 cm have never been measured during the analyzed year, the compared analysis shows that BOLAM forced models performed better than ever and better than the ECMWF forced ones.
In the future, it will be very crucial to accurately forecast the water level outside the Venice Lagoon in order to support the decision-making dealing with mobile barriers raising/lowering to defend Venice from floods. In this framework, a deep comparison between the results obtained inside (Punta della Salute - PS) and outside the lagoon (Lido Diga Sud - DS) was performed (table 1); the results of the BOLAM forced models (6 and 7) confirm a very good performance at DS as well as at PS already 72 h in advance.

	h in adv.	4 std	4ass	5std	5ass	6std	6ass	7std	7ass
DS	72	23.3	21.5	25.7	16.8	12.5	11.8	15.0	12.9
	48	17.5	16.8	18.3	16.0	11.4	11.5	12.2	11.9
	24	11.4	11.3	11.7	12.5	10.3	10.8	10.1	10.2
PS	72	22.0	20.4	24.3	15.0	9.1	8.6	11.3	9.0
	48	17.4	16.3	18.6	15.9	10.2	10.1	11.2	11.3
	24	10.5	10.6	10.8	11.5	12.3	13.3	12.0	12.4

Table 1. RMSE values (cm) calculated for Lido Diga Sud (DS) and Punta della Salute (PS) station during the 29th October for all the model runs at different forecast lag.

As widely shown, the very high sea level event occurred on the 29th of October 2018, reached 156 cm at Punta della Salute. This event has been characterized in terms of exceptionality and rareness through the statistical analysis GPD-POT and GEV (table 2) in many different locations (inside and outside the lagoon) and it could be highlighted that it corresponds moreover to a 20 years return period; it means that it has about 5% of chance of being exceeded in any one year (figure 4).
It has to be highlighted that extreme event statistical analysis does not state a fully certainty of reality, but represents one of the most useful method to project in the future the well known past, on the basis of measured data [6]; the longest the time series, the longest the future information. In this work we dealt with time series length ranging from 15 years (Porto Caleri) to almost 100 years (Punta della Salute); different lengths imply that the probability density could be more or less reliable when calculating very extended return periods. However it could be seen that the highest value ever measured (194 cm in 1966) is absolutely exceptional and out of the range of predictability, having a theoretical return period of almost 1000 years.

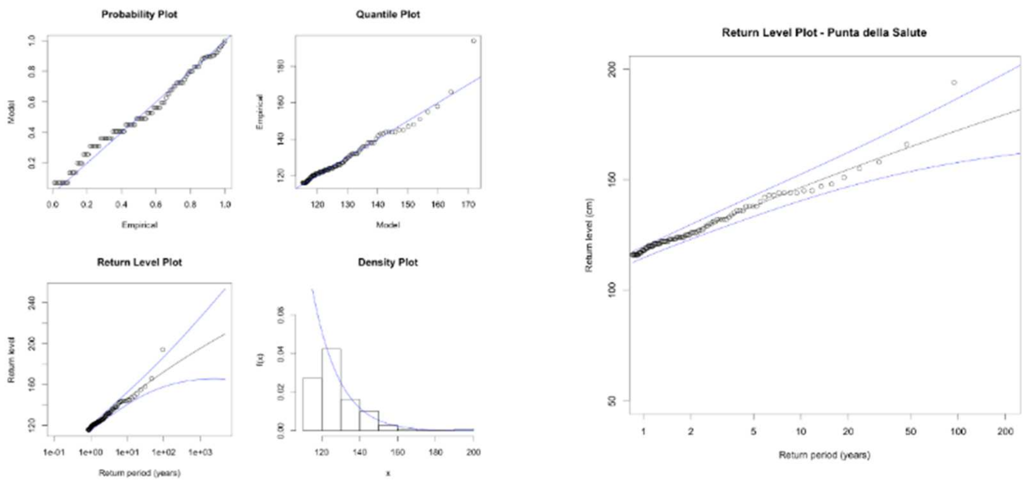

Figure 4. Punta della Salute GPD-POT analysis (left panel), Punta della Salute return level and return period (right panel).

Moreover, the using of two different methods (GPD-POT, and GEV) guarantees robustness and reliability of the results, confirming the correctness of obtained values (table 2).

Return period	1		5		10		20		50		100	
	GEV	**GPD**	**GEV**	**GPD**	**GEV**	**GPD**	**GEV**	**GPD**	**GEV**	**GPD**	**GEV**	**GPD**
BURANO	115	118	137	137	144	143	149	148	155	153	158	156
PORTO CALERI	127	130	147	146	152	151	157	156	162	161	165	164
PUNTA SALUTE	113	117	139	139	148	146	157	155	167	165	173	172
GRADO	128	128	147	146	153	153	159	159	166	166	171	172
CHIOGGIA	118	120	138	139	147	146	156	154	167	164	176	171
LIDO DIGA SUD	121	123	143	143	151	151	158	158	167	166	173	171

Table 2. Return levels and return periods evaluated with two different methods POT-GPD, GEV in the North Adriatic Sea and in the Venice Lagoon.

Conclusions

This work summarises on of the most important activities concerning the flooding risk and management (Flood Directive 2007/60/EC), performed by ISPRA. ISPRA developed and manages the described integrated forecasting system and applies in research activities, in order to monitor, analyse and forecast the physical state of the marine environment at short and medium term and to prevent and mitigate flooding, storm surge, tsunami and extreme wave events impacts and effects.

This operational system and the statistical analysis were developed in order to help the institutional bodies (such as the National Civil Protection Department) that have to deal with the undesired effects associated with *acqua alta* (flooding of Venice and other urban centre in the lagoon, accessibility of harbours, risk of rivers overflow, navigability of the Venice canals) and that need to promptly react and take decisions.

These infrastructures, the monitoring systems and the operational one, open to all stakeholders, aims to share its potential with the scientific community as well as with the institutions responsible for environmental monitoring and defence. They represent a very useful tool to support the management of the marine environment and its resource, in particular regarding the coastal zone planning, protection and management, the assistance to many operational activities, the safety at the sea, the support to the navigation and to the mitigation and rescue actions.

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Faunistic assemblage of the supralittoral zone in the Thyrrhenian coast (Central Italy): the invertebrates inhabiting the Posidonia oceanica banquette

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Introduction

Posidonia oceanica (L.) Delile, 1813 is an endemic marine phanerogama of the Mediterranean Sea. Stranding of dead leaves, rhizomes and fibrous parts of *P. oceanica* is a natural phenomenon that is observed annually on several Mediterranean coasts, especially as a result of the autumn and winter storms. The accumulation of beached biomass, combined with sand, forms the structures known as *banquette* that can reach up to 2 meters of height and develop for hundreds of meters, depending on the geomorphological structure of the coast. In general, *banquette* is made up of *Posidonia* leaves, whose shape and accumulation modalities give the cluster a very compact and elastic lamellar structure. Their elastic nature, however, makes them easily deformable forms of deposit due to the action of the wave motion (AA.VV., 2010).

Banquette, together with its floating fraction, plays an important role in the mechanical protection of beaches from erosion, hindering the action and the energy of waves, thus contributing to the stability of the beaches (De Falco et al., 2008). Moreover, the role of *banquette* is decisive for the life of the biocenosis of the beach, as the products of the accumulated leaves re-circulate large quantities of fundamental nutrients for the flora and fauna of the entire coastline (AA.VV., 2010).

The present work was focused on the invertebrate community of the *banquette* of a mixed rocky/sandy beach from Central Tyrrhenian Sea (Sant'Agostino, Civitavecchia, Italy), with a relatively low anthropic impact. We were aimed at: 1) the analysis of the spatio-temporal distribution (in amplitude and depth in the banquette layers) of invertebrate taxa, and 2) the study of the possible relationship between environmental parameters of the *banquette* (e.g., temperature, humidity and penetrability) and the presence of the different taxonomic groups.

Materials and Methods

The present study was conducted with seasonal samplings over one year (2008), following the working procedure commonly adopted for sandy beaches (Chelazzi et al., 2005; Pavesi et al., 2007) and still used on *P. oceanica* wrack (Deidun et al., 2009; 2011). To facilitate capture of invertebrates potentially located below the surface, we deployed traps at different heights within the wrack layer by keeping the traps operational 24 hours, collecting active animals that moved within the different layers of the wrack. An additional sampling ("layered sampling") was done taking columns of *banquette* at three different depths (0-20 cm; 20-40 cm; 40-60 cm).

The number of traps deployed per sampling date ranged from 21 to 30 for a total of 104 traps during the study. The exact number of traps deployed differed slightly among seasons due to differences in sea level and wrack width and thickness throughout the year. To maintain humidity sufficiently high, a small amount of *P. oceanica* dead leaves was placed in each of the traps. The animals were fixed in 70% EtOH in the field and then sorted in the laboratory.

In the field, temperature and penetrability were recorded at each trap on each sampling date. Temperatures were measured with a Hg thermometer at 11 a.m., whereas penetrability was calculated as the portion, in centimeters, of a metallic probe penetrating the wrack when dropped vertically from a height of 1 m. At each height level, *P. oceanica* wrack samples were also collected so as to calculate water content (measured in the laboratory as the difference between the weight of a wet sample and its dry weight after a 48h storage at 60 °C).

In the laboratory, the captured invertebrates were counted and identified to genus level and in many cases also to species.

Results

• 29,009 individuals belonging to various taxa were collected within beached debris.

• Amphipoda (Crustacea) was the most abundant taxon (19,585 individuals). Three talitrid species have been found: *Orchestia gammarellus* (Pallas, 1766), *Orchestia montagui* (Audouin, 1826) and *Orchestia mediterranea* (Costa, 1853). The talitrids were present along the transect with greater frequency of capture in the winter season (humidity > 50%, and temperature > 10 ° C). This seasonal / temporal preference was confirmed with the Non-metric Multidimensional Scaling (NMDS).

• Isopoda (Crustacea) were less numerous (1,228), but with a higher species diversity than that found for amphipods. The species closely associated with beached *P. oceanica* were: *Buchnerillo litoralis* (Verhoeff, 1943) (27.04%), the most abundant, with general body depigmentation and microphthalmia, *Stenoniscus pleonalis* (Aubert and Dollfus, 1890), and *Armadilloniscus candidus* (Budde Lund, 1885). These species were distributed differently within the *banquette*; in particular *B. litoralis* and *S. pleonalis* were more abundant in the deeper layers of the *banquette*. *Tylos ponticus*, on the other hand, colonizes the most superficial layers and the oldest and drier beached debris.

• Three halophilous species of Pseudoscorpiones, novel for the Lazio coast were: *Paraliochthonius singularis* (Menozzi, 1924), *Chthonius* (*Chthonius*) *halberti* (Kew, 1916) and *Pselaphochernes litoralis* (Beier, 1956). These three species are typical of both sandy and rocky coastal environments and are known only for few Italian locations (Gardini, 2000; 2010).

• Layered sampling has proved to be the most efficient method for the survey of Geophilomorpha adapted to living in the supralittoral zone, such as *Tuoba poseidonis* (Verhoeff, 1937) and *Pachymerium ferrugineum* (C.L. Koch, 1835).

• The diversity index of Shannon-Weaver (H) showed minimum values for winter traps and spring surface traps, according to the dominant presence of amphipods and the reduced abundances of the other taxa. In autumn, the traps were characterized by high values for H index because of the strongly reduced frequency of the amphipods and, at the same time, of the presence of all other taxa.

Conclusions

The richness in species and the relative abundance of the different taxa suggested a good ecological quality of the study site. For the transect, the variables that most affected the presence of species were temperature and humidity, while penetrability seems to be decisive for the presence of *B. litoralis*. Our data are in accordance with those obtained by several authors that showed that abundance and diversity of the different taxa from sandy beach-dune ecosystem vary over time (Colombini et al., 2009). Our data indicated that the succession of the species is regulated by different factors: adaptation to specific micro-environmental conditions of wrack, adequate trophic resources, inter-specific interactions.

In our study site, wrack provided the greatest resource of carbon and organic material for macrofauna and allowed species to occupy a range of different trophic levels that include primary consumers, detritivores and predators.

Shape, extension and the relatively stability trough space and time of *banquette* at the study site allowed the development of a diversified faunistic assemblage, composed of species whose presence is closely linked to wrack. Notably, the isopods found at Sant'Agostino *banquette* were characterized by reduced size, a clear adaptation to movements in the small spaces between stranded leaves of *P. oceanica.*

Our results indicated that the presence of stable *banquette* assures individual abundances, relatively high species richness and a high trophic diversity. Results from our study suggested that beaches with stable *banquette* show a higher biodiversity than that found in beaches where wrack is periodically removed, as reported by Deidun et al. (2009).

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Biodiversity response to a rapid water level oscillation: the case study of Lake Bracciano (Central Italy)

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1-Introduction

Rainfall variation, open water evaporation and human extraction play an important role in the response of Lake water level oscillations. The changes in the lake water level recorded in the last years (-198cm recorded in November 2017 with respect to the reference level), accompanied by the retreat of the shoreline up to 100m (Rossi et al, 2018), induced changes in the shape of the coastal line geometry, related to the lake floor morphology, affecting water circulation and favouring the loss of large amount of organisms (ISPRA, 2017). These last aspects directly influenced also the self-purification processes (Ostroumov, 2017). It is widely recognized that lakes are ecosystems (Galloway et al. 2003; Kendall et al. 2010) with high ecological and economic values. For example, biodiversity increases professional and sport fishing, makes the habitat attractive for tourism, and makes fresh water suitable for drinking (Calizza et al. 2017). For these reasons it is fundamental to manage a sustainable use of freshwater resources taking into account not only the amount of the whole available water volume, but also the system's response to the rainfalls oscillations, natural evaporation, human extraction and species distribution. The main goal of the current research was to describe and understand the relationships between the declining lake level (Rossi et al. 2018) and the effect of the shoreline changes with direct consequences on biodiversity and ecosystem services (Rossi et al. 2010; Costantini et al. 2018). The results have been achieved by monitoring the spatial and temporal changes occurred in the lake Bracciano from 1998 to present. Monthly precipitations, seasonal daily evaporation rate, variation of the coastal line and water circulation, loss in water surface and volume have been investigated. Furthermore, experimental evidences, collected at Lake Bracciano, have been used to understand and predict potential effects of loss of littoral lake areas on food web structure, fish diversity and biomass, with a particular focus on the invasive species Micropterus salmoides and its impact on autochthonous fish species, including some of commercial interest. The water level oscillation linked to important changes in coastal line, allowed us to predict, with a geostatistical model, a possible re-distribution of invasive and autochthonous species.

2-Study area

Lake Bracciano is a sub-circular volcanic lake located 32-km Northwest of Rome (Latium, Italy), belonging the Sabatino Volcanic District (Peccerillo 2005; Manca et al. 2017). It has 57.58 km2 of surface area, a total volume of 5.13x109 m3 and a circular perimeter of 31.981 km (Rossi et al. 2018). Lake Bracciano elevation is 163.04 m a.s.l. (altitude of the Arrone River emissary) with a maximum depth of 165 m (Fig. 1). It's hydrological and hydrogeological basin replenishment is closely related to precipitation and infiltration processes (Ayenew & Becht, 2008). The lake is oligo-mesotrophic (Rossi et al. 2010; Costantini et al. 2012) and it is characterized by the abundance of several fish species of commercial interest. The distribution of such species is related to both riparian and aquatic vegetation coverage (Azzella, 2014) linked to the morphology of the lake bed.

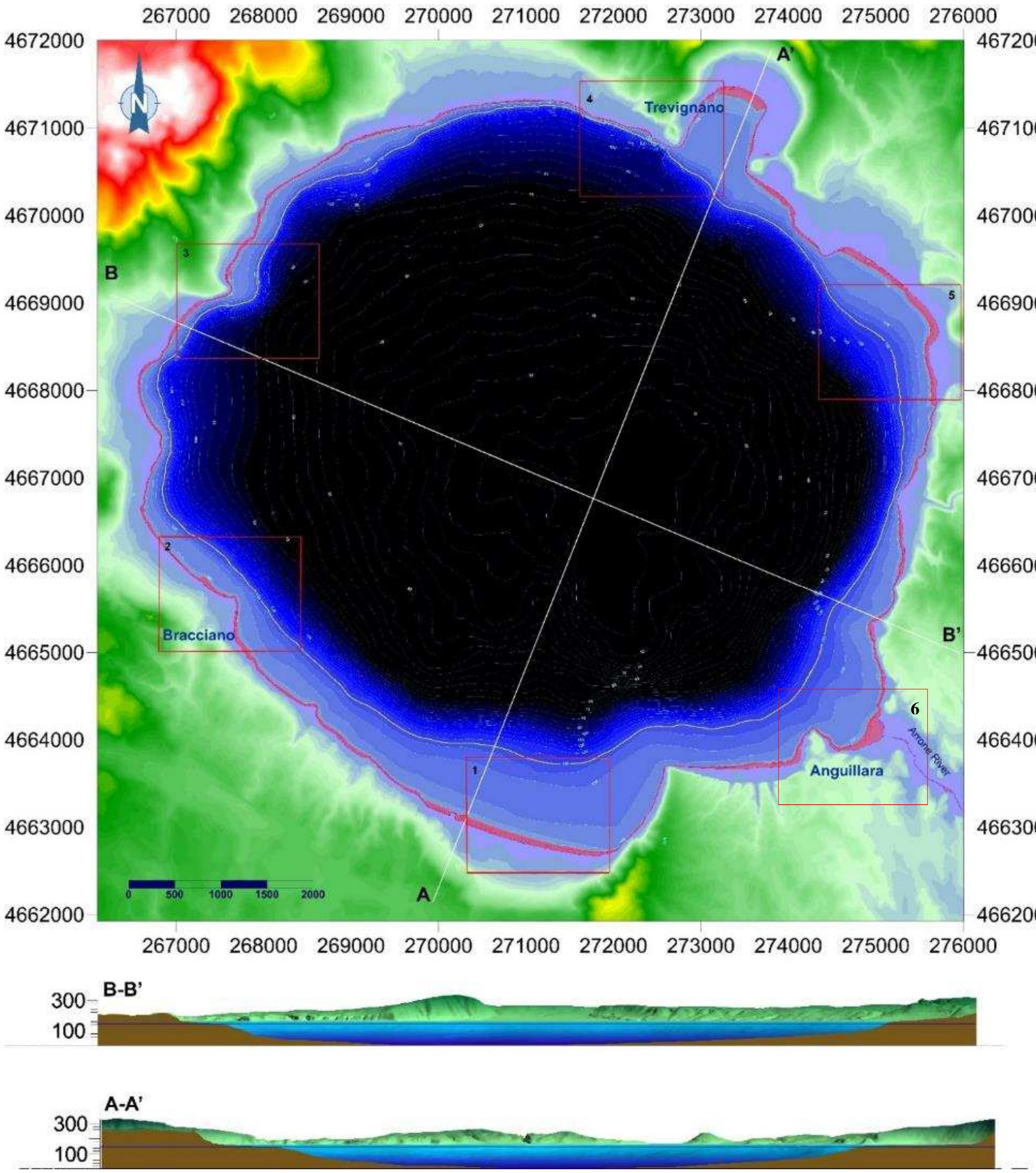
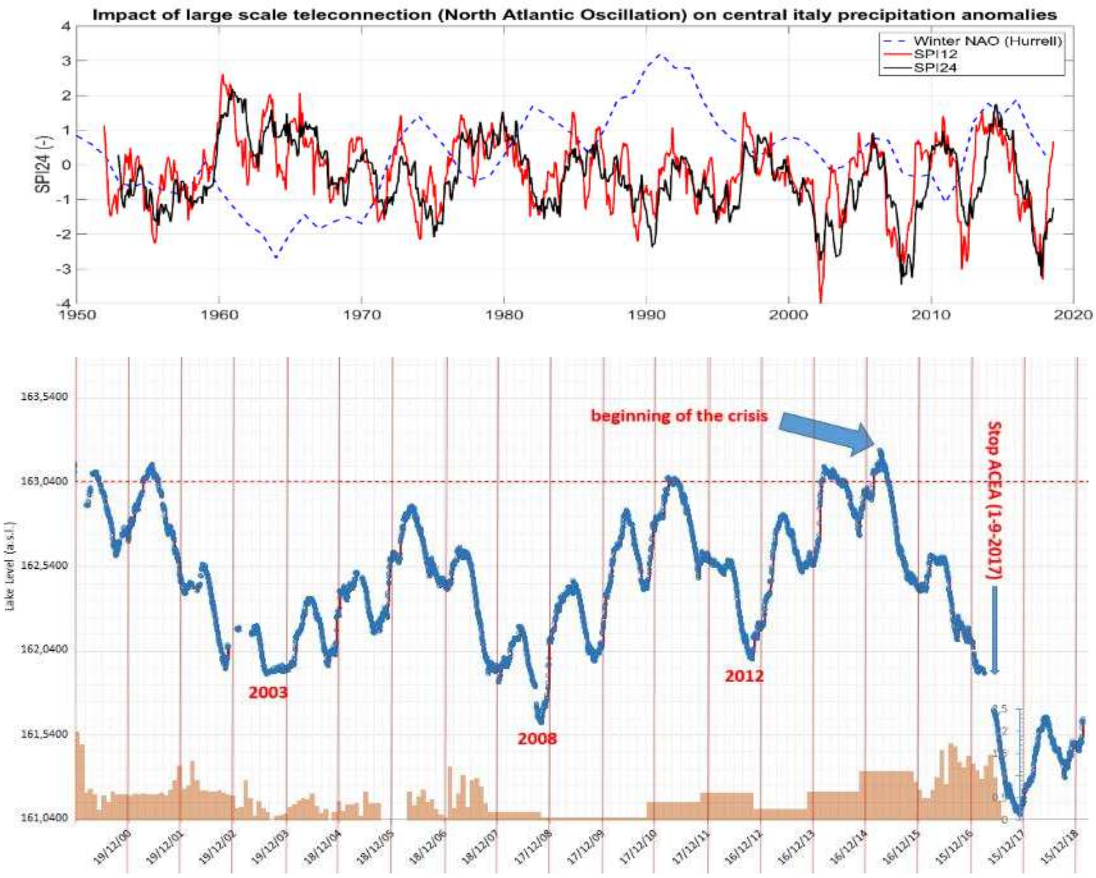


Fig. 1 – Contour maps of Lake Bracciano using the new and up to date Digital elevation model (from blue 0m to red 600m a.s.l.), bathymetry (sky blue lines). Red levels represents the coastal surface loss in the last 3 years. Lines represent cross section traces, while the insert boxes maps are showed in Fig. 3.

3-Result

In the last five years Lake Bracciano was involved into a unique negative water level variation never recorded before, with an absolute minimum in 11/2017. As discussed in Rossi et al. (2018), such reduction is mainly to be attributed to pluriannual precipitation deficit, further exacerbated by increased potential evaporation and human extraction. Since such minimum, despite a slightly positive precipitation anomaly at annual scale registered in December 2018 (SPI12, Fig. 2a) and the interruption of human extractions (9/2017, Fig. 2b), lake level still remained low (Fig. 3), showing only a partial recovery phase in the last year (+30cm in xxx). Therefore, the shape of the shoreline and coastal water circulation are drastically changed with a possible impact on the distribution and abundance of biodiversity (Costantini et al. 2018).



a

b

Fig. 2 – a) Annual (SPI12) and Bi-annuals (SPI24) precipitation (modified after Romano et al., 2017 in collaboration with Central Appennine District); b) Variation in the water level of Lake Bracciano and monthly extraction from the lake.

The lake water level changes recorded in the last years (from 2000 to present), which are confirmed by manual measurement performed during the last year, leave no doubts about the significant rise of the shoreline (100m maximum at the end of 2017 Year with respect to April 2017). The current situation (February 2019) sees a lowering of the lake level equal to -160cm from the Arrone emissary altitude above sea level. The reconstruction of the digital model of the lake cuvette (Fig. 1) has allowed quantifying the effects of the lake level oscillations on the shoreline location. Such a lowering exposes the lake system to significant risks with a loss of self-purification surface evaluated in -22.5% of loss, and loss of macrophytes that represent a key element of the aquatic ecosystems (Carpenter & Lodge, 1986).

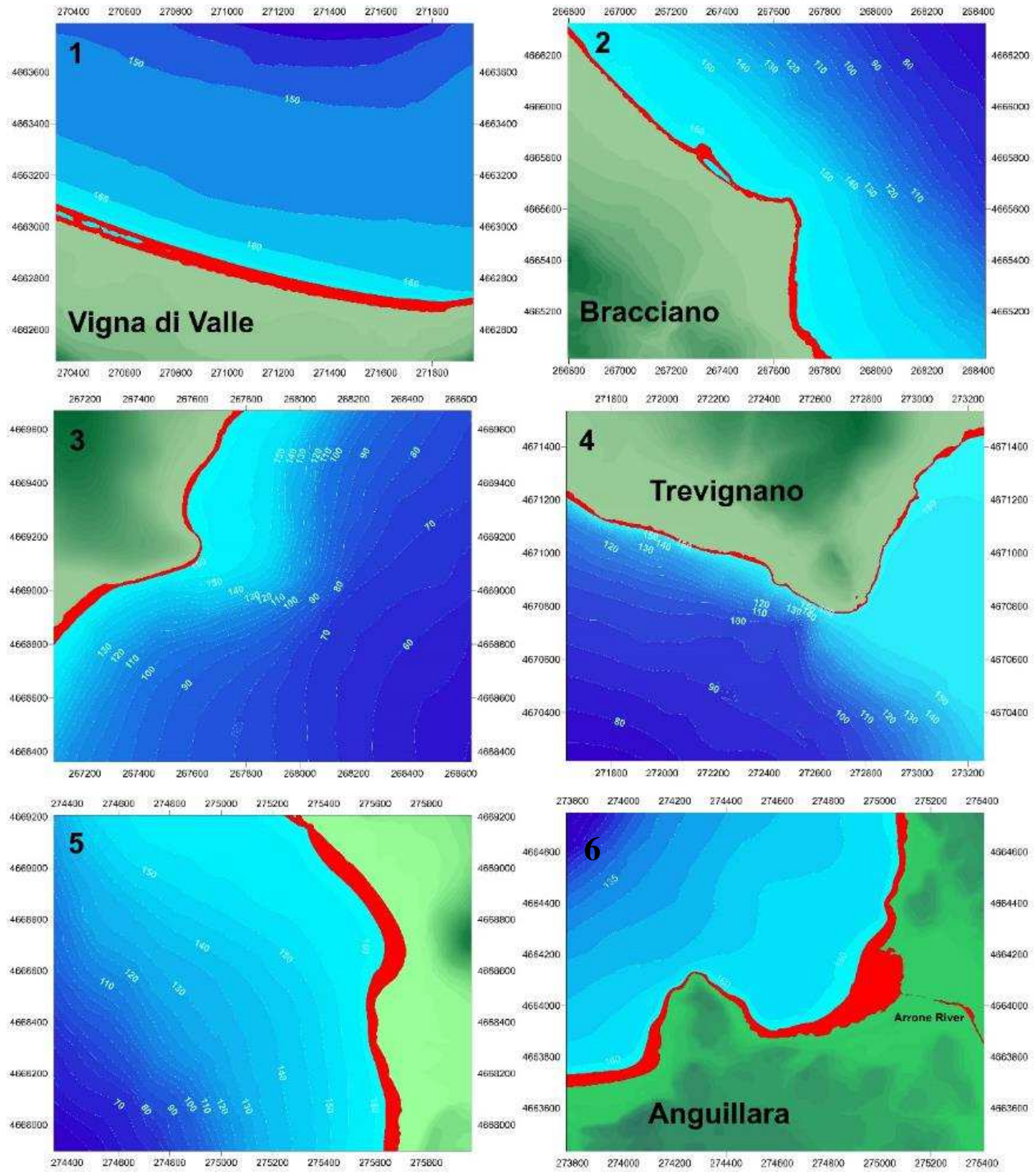


Fig. 3 – Maps of six coastal lines showing the current shoreline trend (February 2019). In red the coastal surface loss (-160cm from hydrometric zero).

Recently, Costantini et al. (2018) provided evidences that some species can vary its diet and, as a consequence, its trophic level in the invaded food web, even within a single lake, adapting to local ecological conditions of littoral lake areas. The study by Costantini et al. also showed that the invasive fish *Micropterus salmoides* here after called “bass” reached a higher density in the less productive area of the lake, where the food web was composed by a lower number of species and trophic links, than what observed in the more vegetated and productive area. The South side of the lake is characterised by a gently sloping bottom, in contrast to the sharper slope observed in North (fig 1, fig.3$_{1-6}$). Consequently, both riparian and aquatic vegetation coverage are higher in South than in North, as well as macroinvertebrate density. Specifically, Chara spp. and Phragmites australis, the two taxa dominating the aquatic and riparian vegetation respectively, had a coverage of 50-55% and 25-30% in South respectively, while they were extremely scarce (<5% of coverage) in North (Rossi et al. 2010). In parallel macroinvertebrate density varied from South than in North: 711.9±123.8 individuals in South to 311.4±34.9 individuals in North. Richness, abundance and diversity of autochthonous fish species were all higher in South than in North. Therefore, the number of trophic links and food web complexity were also higher in South. In contrast, *M. salmoides* was more abundant in North (45±3 vs. 18±2 individuals). Specifically, the abundance of the invader and its impact on autochthonous fish species were both lower in the more species rich and complex food web. Experimental tests demonstrated that the cost of feeding on fish prey by *M. salmoides* increased with habitat complexity, due to increased handling time of prey and reduced attack success rate. By reducing its trophic position in the food web, the bass experienced significantly stronger competition with the numerous fish species found at intermediate trophic levels in this location, which can explain the link between higher vegetation coverage and habitat complexity and lower abundance and impact of the invasive species. High vegetation coverage and productivity should be considered the main factors allowing a higher diversity and abundance of fish to colonize the littoral lake area with respect to what observed in North, where a sharper slope significantly reduced bottom vegetation coverage. As a consequence the lake water level variation recorded since 2015, accompanied by a significant retreat of the shoreline, favorite the loss of important amounts of lake bed specially in the southern sector. This effect favorites the loss of important quantities of aquatic vegetation coverage that directly drives the biodiversity of the lake Bracciano. With such asymmetric lakebed loss, autochthonous fish species are strongly disadvantaged, with a possible re-distribution of the invasive species, and an increase in its impact due to increased fish consumption.

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Posidonia oceanica banquettes: a resource for the marine-coastal environment and a natural defence for the coasts

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Introduction

Posidonia oceanica (L.) Delile is a marine phanerogam endemic to the Mediterranean Sea present along the most significant part of the Italian coasts. It forms dense and extensive green meadows and provides essential ecological functions enhancing coastal biodiversity. This marine plant has roots, stem, long ribbon-like leaves grouped in bundles, flowers and fruits (sea olives) and grows preferentially on sandy bottoms. It lives between the surface and 20 - 45m of depth in very clear waters, with relatively constant salinity values (36 ‰ -39 ‰) and temperatures between 10 and 28 ° C (optimum between 17 ° C and 20 ° C). Its growth mode leads to the formation of terraced and compact structures, the so-called *matte* consisting of the intertwining of layers of rhizomes, roots and trapped sediment.

The *P. oceanica* meadows offer protection to many marine organisms, are a nursery area and have considerable ecological value and constitute a complex ecosystem in terms of richness and biotic interactions. Due to its ecological role in marine and terrestrial ecosystems, *P. oceanica* meadows are identified as a priority habitat type for conservation under the Habitats Directive 92/43/EEC [1] and a good indicator of the quality of marine-coastal waters due to its sensitivity to changes in environmental conditions (Framework Directive 2000/60 / EC).

The beaching of *P. oceanica* remains (leaves, rhizomes, fibrous remains) and other marine phanerogams is a natural phenomenon, observed annually on many coasts, especially following the autumn and winter storms. The accumulation of beached biomass, combined with sand, forms very compact and elastic lamellar structures known as *banquettes*.

The *banquettes* have variable thicknesses, reaching up to 2 meters in height and hundreds of meters in length, depending on the geomorphological layout of the coast. Posidonia *banquettes* have an essential role in beach protection from erosion [2] and promoting the origin of the coastal dunes.

These structures can absorb the energy of the wave motion, reducing its erosion capacity during the demolition phase during the storms, thus contributing to the stability of the beaches.

The *banquette* plays an active role in retaining sediment that remains trapped in its layers of leaves: it is calculated that $1m^3$ of *banquette* can maintain about 40 kg of sediment.

This functional buffer is strictly connected to both dimensional and temporal parameters (stability of the *banquette* and construction process frequency).

The floating fraction in the water leaves and the fibrous remains of Posidonia also constitutes a dense suspension that helps to dissipate the mechanical energy of the waves. In any case, the elastic nature of the banquettes makes them transitional and easy to deposit deformable by the action of the incident wave motion to which they are subject.

Moreover, the leaf litter represent an important temporary sink of biogenic elements, playing a fundamental role in the nutrient budget of *P. oceanica* meadows [3] but also for the pioneer vegetation of the beaches and that of the dunes.

Banquettes: the problem and management

The occurrence of *P. oceanica* remains within touristic areas may represent a problem to manage, since most of the beach users, still ignore their ecological role and value and consider the plant remains as foul-smelling rejections rather than natural components of the coastal ecosystem.

The accumulations of *Posidonia oceanica* on the beach become a "problem" to be managed when they are located on the shores of the tourist-bathing interest and their presence is not appreciated by beach users and swimmers who generally consider it a foul-smelling rejection rather than a natural component of the coast, with essential ecological functions [2].

The bather is also discouraged in the use of the bathing area due to the nuisance caused by floating residues that adhere to the exposed parts of the body, for the smell, sometimes perceived, generated by the degradation processes in progress or because their presence is a limiting factor for the recreational use of the beach [2].

To avoid a decrease in the tourist value of the beaches, local administrations are pushed to remove such deposits before the beach season to make the beaches more pleasant and usable.

It often applies temporary and emergency solutions that include costly collection and landfill disposal in addition removing, to the leaves and other remains of Posidonia, large quantities of sand without taking into account the nature of the coast on which action is taken.

This means compromising the integrity of the coastal habitat and triggering or accelerating erosion, forcing local administrations to take measures to protect the coast and nourish the beaches.

The management of the stranded plant biomasses is not easy at present because they lack rules and models shared at the national level and also the legislation in force does not frame these materials in a transparent way as waste.

At present, the management of beached plant biomasses is not easy because there are no rules and models shared at the national level and moreover the current legislation does not frame these materials in a transparent way as waste.

In 2006, the Italian Ministry of the Environment has released an official document concerning the management of *Posidonia* beached accumulations [4]. In this document, the ecological role of *banquette* and the beach protection against erosion have been recognized; the following management solutions have been indicated: 1) maintenance of *banquettes* on site; 2) reallocation of accumulations within the same beach/ within beaches not accessible/ not used by swimmers / particularly exposed to erosion; 3) removal and landfill in accordance with the current legislation.

To deepen knowledge on the topic, understand the problem, evaluate the magnitude of *Posidonia oceanica* accumulations at national level and, know the management methods adopted locally, ISPRA (Italian Institute for Environmental Protection and Research) has set up and coordinated a specific working group with some Italian Coastal Agencies (ARPA) also for to reach shared management solutions at national level and to provide a basis for defining sector regulations.

For this purpose, specific forms were prepared and sent to approximately 400 coastal municipalities to collect in particular information on the location of the banquettes or *Posidonia oceanic*a remains, management methods and procedures adopted locally and costs incurred by municipalities.

The data obtained were collected in the ISPRA document "Formation and management of *Posidonia oceanica banquettes* on the beach" [5].

The study showed that along the Italian coasts the removal and landfill of Posidonia accumulations before and during the bathing season is the management practice most commonly adopted by coastal municipalities, to allow the beach tourism.

However, in this way, large quantities of sand are removed, the beaches are exposed to erosion and then to subsequent nourishment interventions [5].

The on-site maintenance of the *banquettes* is the best management solution from the ecological point of view, and the one that is more consistent with the principles of protection and conservation also expressed in the SPAMI Protocol of the Barcelona Convention [5].

It should be carried out when there is no conflict with users' bathing requirements in this way, do not interfere with the role they play in protecting against the erosion of coasts [5]..

The ecological beach model

To avoid further action of removal of Posidonia *banquettes* with negative consequences for the beach ecosystem, ISPRA is promoting the "ecological beach model" which consist in on-site maintenance of the *banquettes* and eco-sustainable management [2, 6]. The "ecological beach model" is a new management practice for the *P. oceanica* on the beach which can be supported by training and informing citizens, to produce a change of opinion on beached accumulations: from waste to environmental and economic resource.

Moreover, ISPRA is proposing this model as a new criterion for the assignment of the Blue flag by FEE Italy [2]. The so-called "ecological beach" contributes to enhancing both the ecological and functional role of the banquettes for the beach ecosystem and the circular economy. The implementation of the Ecological Beach Pilot Model and its success require the use of the best management solutions and procedures from an ecological point of view, but also the involvement of the beach users and managers in environmental training and education initiatives, with local demonstration prototypes.

About that, an informative poster was developed by ISPRA to inform citizens about the meaning and the ecological-functional value of the model to encourage the change of opinion regarding the presence of the banquette and re-evaluate the concept of natural beach [6] (Figure 1). Such posters can be placed on Italian shores and encourage conscious bathing tourism. Environmental education activities, both in the field and at school, are carried out to promote the ecological beach. To subtract the Posidonia *banquettes* by the waste cycle and enhance it from an environmental, and functional point of view when it stayed on the beach when it recycled in various productive and commercial sectors (e.g. compost, insulating panels, cosmetics, filling of seats, etc.). Also, specific information for shoreline managers will aim to produce management support and to maintain the ecological beach model in the future.

Fig. 1. An example of the poster developed by ISPRA to inform citizens and beach users [6].

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6 - Posidonia oceanica spiaggiata: la gestione degli accumuli e la valorizzazione

http://www.isprambiente.gov.it/files/temi/Cartellonistica_Posidonia_2018.pdf

Measuring meteotsunamis in sea and connected inland waters with ultrasonic sensors

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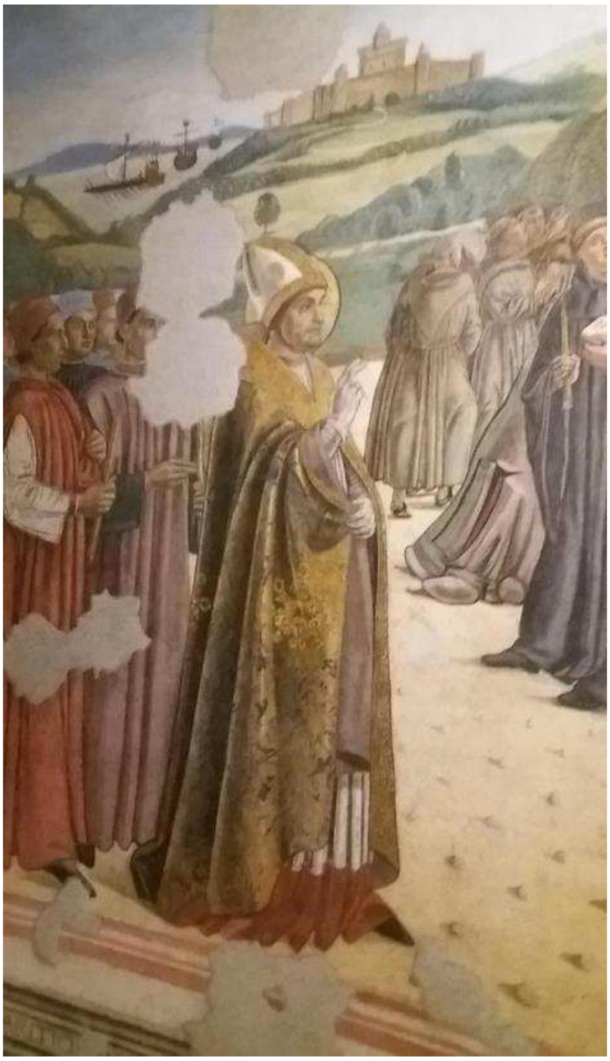
Abstract

Local atmospheric pressure variations induce global sea level oscillations propagating in the sea according to the bathymetry. A simple tool to measure the long waves has been realized with distance ultrasonic meters in 2006/7 and with Arduino components in 2019 connected to a pc. The experiments on the long waves propagation conducted by using the first instrument in San Vito Marina (Adriatic Sea, during the passage of a squall and the production of a small meteotsunami) and Ostia Lido (Tyrrhenian Sea) are described. New insights are provided for the present-day device firstly to examine the tides, along with the currents, in the canals of Venice, to realize the experience proposed to Galileo by Father Rinuccini, then to measure the tides in the Church of St. Francesco in Ravenna, where the water gets to the crypt especially during the equinoxes when the tides are larger and lastly to evaluate the dynamics connected with the conservation of this masterpiece.

1. Introduction: Tides in Antiquity, in Middle Ages, till Galileo

In the Ancient Egypt (Russo,1996) Alexandrinian scientists described the hypothesis about the presence of an intermediate continent between Asia Eastern coasts and European Western ones through the observation of tides.



Furthermore, Galileo Galilei in his Dialogo sopra i Massimi Sistemi wrongly used astronomical tides as the actual demonstration of Earth's rotation. Repeatedly Father Rinuccini, from Venice, asked Galileo to conduct some experiments with a pole in the canal in front of his house (Gatti, 2018). Galileo did not answer to these inquiries, probably aware of the long time needed for reducing all the observations.

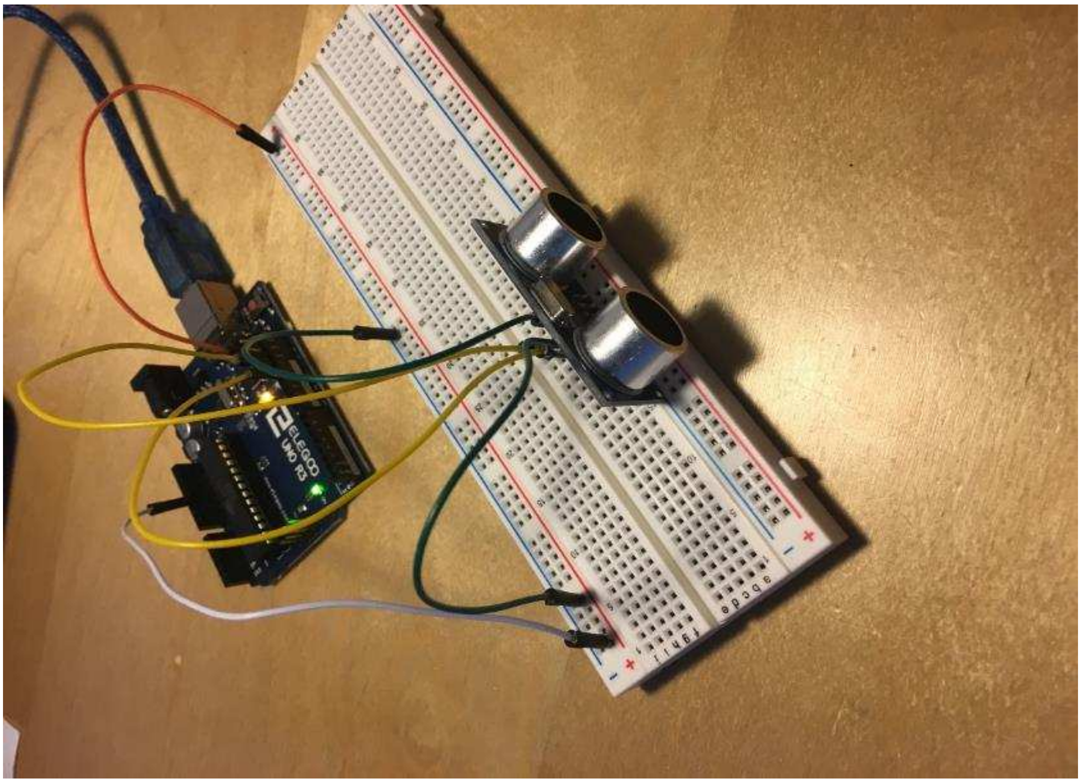
During the middle ages the science of tides remained dormant, whereas the periodicity of the tides in the places where they were more prominent was studied thoroughly. A fresco of Antoniazzo Romano and Melozzo da Forlì (Chapel of Cardinal Bessarione, recently accessible to the public, Basilica of SS. Apostoli in Rome) shows a ceremony on the shore of Mount Saint Michel, during low tide. The shells are numerous and visible on the ground. Sea ships and Mount St Michel appear in background. Being aware of the speed at which the tide rises, ceremonies like the ones showed should have been prepared carefully.

2. The ultrasonic devices

The first device developed in 2006/7 is now being upgraded into an Arduino-based device.
It consists of 5-pin compatible Arduino ultrasonic sensor HC-SR05 model

one for the direct current 5V

one for the triggering signal (a quadre wave at 40 KHz frequence lasting 1.6 ms, made with 10 microsecond pulses separated by 200 microseconds),
one for receiving the echo (within 38 ms, i.e. 12 meters round trip of the signal, so at maximum distance of 6 meters)
one for ground connection
another pin, useful to introduce other data (temperature and/or moisture) to compute the real-time velocity of sound
The space resolution of this device is 2-3 mm, and a number of measurements per second are already averaged for the normal uses of this device (e.g. parking cars). The maximum distance declared is 450 cm.
The angle of measurement, field of view, FOV is 15°. This is the device mounted and connected to the computer.



The maximum distances of measurement can be arranged through modifications in Arduino library.[2]

The Echo pin signal "high" corresponds to the return signal of the trigger, and gives us the distance of the target.

The target of ultrasounds is the water surface. In the case of the sea, the surface is rough and an average over a full minute is needed. The detector should stay at least 2 meters away from the water to avoid humidity and drops.

In the case of canals and the crypt of St. Francis in Ravenna the detector deals with calm water, and a lower rate of acquisition can be used.

The latter cases correspond to water surfaces having responses to the tidal forcing much slower than the open sea, and inner basins like natural and artificial harbours, as well as bays or fiords.

3. Long waves, a review

3.1. Waves profiles

Ordinary sea waves have heights $W \leq \frac{1}{30} \lambda$ (Accordi and Palmieri, 1987); and cannot be steeper than $W \sim \frac{1}{7} \lambda$ (Bascom, 1964) for sea water viscosity. The steepness of a wave $s=W/\lambda$ is index of the wave's energy (Ricci Lucchi, 1992). This concerns the FOV of our device and its time rate requirement.

2https://github.com/Martinsos/arduino-lib-hc-sr04/commit/92e6e26b58a9a30fe707713532b528bd442c7a14

3.2 Tides

Those waves are excited by the Moon and the Sun, their period is T~12.9 hr~45000 s (half lunar day) and their wavelength λ~20000 Km at the equator (half equatorial circle). Their velocity is v~ 450 m/s, which would require an uninterrupted ocean depth of 20 Km, for travelling as shallow water waves. Since average oceans' depth is less than 5 Km, and there are continents among them, ocean tides are much slower and they orbit around amphidromic points of zero tides. Evidence suggest that most tidal energy is dissipated daily in shallow seas with large tides, such as the Bering Sea and those around Great Britain and Australia (Knauss, 1997, p. 243). This process allows energy exchange between Earth spin and lunar orbit (Goldreich, 1972) and Earth spin slows down while Moon's orbit radius enlarges gradually.

3.3 Seiches

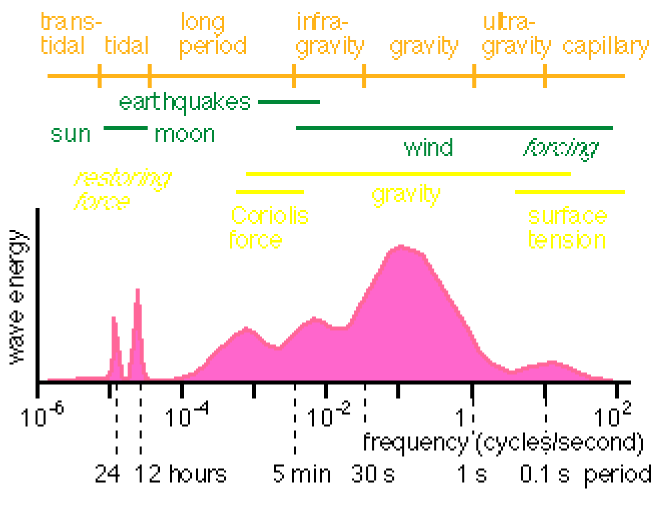
Standing waves with multiple frequencies of shallow water crossing time of a given basin are set up by winds and pressure disturbances. For a rectangular basin (a x b) and average depth h there are $\nu=n\sqrt{gh}/2a$ and $\nu=n\sqrt{gh}/2b$ with integer n=1, 3, 5,... (Csanady, 1984). Seiches in small harbours have 1 hour of decay time (Yanuma and Tsuji, 1998), while in Adriatic sea have an e-folding time of 11 hours.

3.4 Tsunamis and meteotsunamis

Tsunamis are low-frequency ocean waves generated by submarine earthquakes. The sudden motion of seafloor over distances of a hundred or more kilometers generates waves with periods in the range T~10-60 minutes. A quick estimation shows that $T\sim\Delta l/\sqrt{gh}$, where Δl is the dimension of the source and h its depth.

Their name is Japanese for "harbour wave". They were used to estimate the depth of the Pacific Ocean in 1856, when direct measurements were virtually impossible, by observing their phase speed. For North Pacific the result was 4200-4500 m, a considerable improvement on the previous estimate of 18000 m (Tomczak, 2005). Typical e-folding decay is 22 hours in open oceans (Van Dorn, 1984), and the damping is due to bottom friction and turbulence.

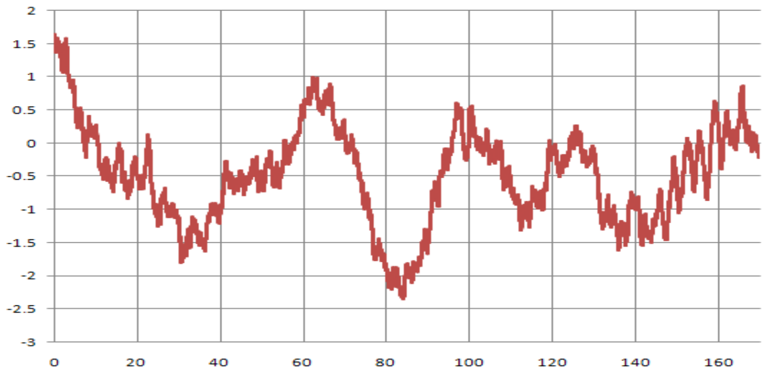
Tsunamis can be generated also by storm surges or other pressure disturbances and they are called meteotsunami. An impulse of 1 hPa corresponds to a change in local mean sea level of 1 cm, this impulse starts to propagate as shallow water wave.



Sketch of the relative amounts of energy as a function of wave frequency in ocean waves. The top (gold) line represents the classification based on period, the line below (green-coloured) shows the classification based on the wave-generating force, and the bottom line (yellow) the classification based on the restoring force. We are focusing here on waves with periods 60≥T≥5 minutes

4 Data

The following data have been realized with a device made by Giovanni Bernardini and published in Sigismondi (2008)

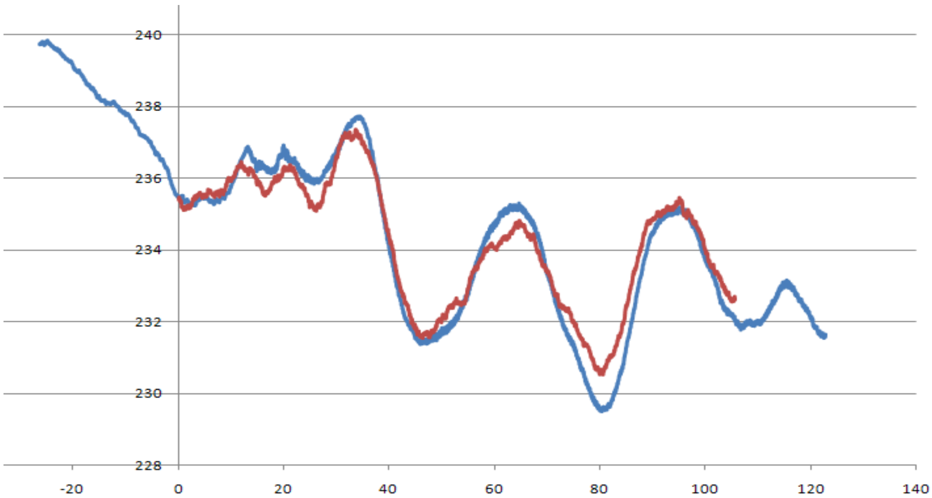


Y axis, mean sea level fluctuations [cm]. X axis, time [minutes].

Data obtained during a sea storm 100 m inside the fishery canal port of Ostia. 4- minute edge waves disturbances are visible superimposed to main seiches of 30-40 minutes periods. Open sea waves of 2 m height were measured during that storm. Running average on 8 minutes and tidal trend averaged on 25 minutes subtracted; other combinations of averages show similar patterns.

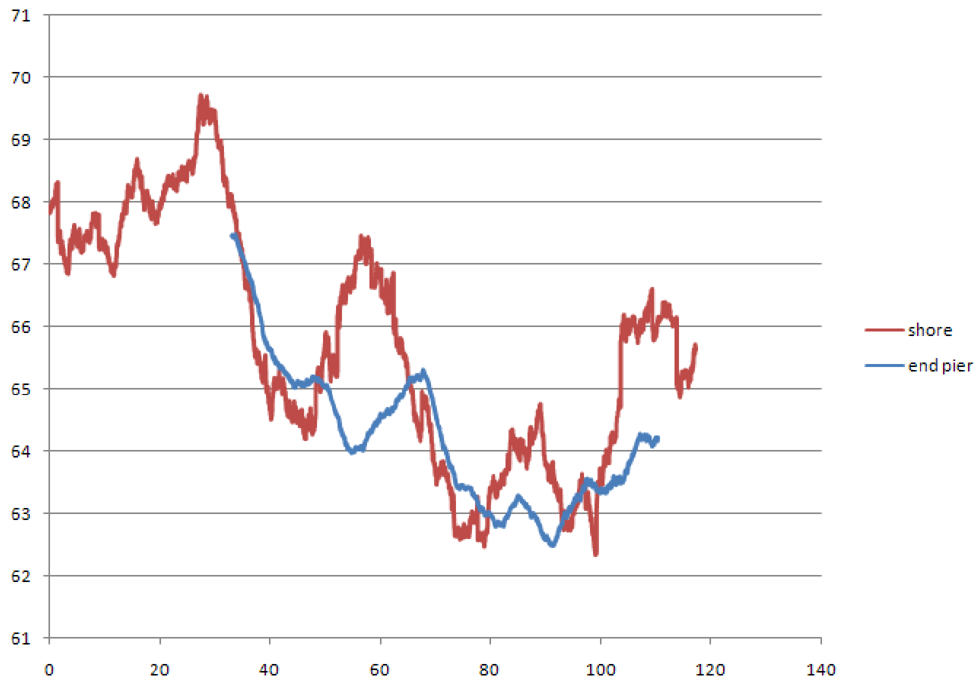
4.1 Solitary waves

Velocity experiment along shore (Lido di Ostia, Tyrrhenian Sea)



Data of August, 25 2007. Two observers located at 523 m of relative North East (red)- South West (blue-longer duration) distance, both at 10 m offshore. Such waves seem to have same phase and slightly smaller amplitude for NE location than SW. Those data suggest a wave front parallel to the shore. Y axis, distance of detector from mean sea level [cm]. X axis, time [minutes].

Velocity experiment perpendicularly to the shore (S. Vito Marina, Adriatic Sea)



Data of September 4, 2007 with very calm sea conditions. Y axis, distance of detector from mean sea level [cm]. X axis, time [minutes]. Running averages over 10 minutes (shore) and 6 minutes (end pier, 180 m offshore).

Smaller amplitude waves for the observer located 180 m offshore. Different patterns. Possible antiphase between the simultaneous tracks, with a node located between the two observers; or combination of direct, incoming from offshore, and reflected waves.

5. Perspectives with the new Arduino device

Measuring tides is deeply important in terms of pedagogy, since their understanding is a major breakthrough in the history of science. The behavior of the tides in Venice could have been crucial for the scientific debate between Galileo and the Catholic Church (Gatti, 2018). Our Arduino device can be adapted to Venice and in two months giving the data that Galileo needed to fully understand the problem, adapting the OUT channel for the direction/velocity of the water current.

About the crypt of St. Francis in Ravenna, there is the possibility to study the time-delay of the water-level with respect to the sea average level, and to understand the impact of the storm surge phenomena to this artwork of the tenth century AD, to prevent problems of static nature and artistic.

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