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# GEOMORPHOLOGIC RISK ASSESSMENT ALONG APULIAN COAST (SOUTHERN ITALY). THE STUDY-CASES OF TARANTO AND BRINDISI SURROUNDINGS AREAS

**ABSTRACT:** PIGNATELLI C., PLANTONE M. & ROMANIELLO L., *Geomorphologic Risk Assessment along Apulian coast (Southern Italy). The study-cases of Taranto and Brindisi surroundings areas*. (IT ISSN 1724-4757, 2006).

The environmental and morphological survey carried out in two test areas along the Apulian coast allowed the main features of the coastal system to be identified, since they are useful to outline the coastal dynamic and the anthropic impact as well. At first, the collected environmental data (geomorphologic, wind/wave and meteorological data) have been converted in numerical data to calculate the Value (V), Vulnerability (U) and Hazard (H) in the investigated areas. These are in fact the three elements to be considered for the definition of the Environmental Risk, a very important element for territorial planning.

The analysis of collected data has been important to infer the causes of different geomorphic processes and human factors influence on the coastal environment. Geomorphologic risk assessment has been computed using R=VUH formula (UNESCO, 1972). A risk map summarizes the obtained results. In particular, two test areas have been investigated: the first one is a pocket beach stretching along the Adriatic coast of Apulia between Torre Canne and Torre San Leonardo (Brindisi), the second one is placed to Ionian coast of Apulia between Capo San Vito and Blandamura Pinewood (Taranto).

KEY WORDS: Geomorphology, Environmental Impact Assessment, Risk, Apulia coasts (Italy).

**RIASSUNTO:** PIGNATELLI C., PLANTONE M. & ROMANIELLO L., *Valutazione del rischio geomorfologico lungo la costa della Puglia (Italia): i casi studio dei dintorni di Taranto e di Brindisi.*

Lo studio morfologico-ambientale sviluppato in due aree campione della costa pugliese ha permesso di individuare le principali caratteristiche del sistema costiero, utili a delineare e l' impatto antropico e i suoi effetti sulla dinamica costiera. I dati ambientali (geomorfologici, ondametrici e anemometrici) e quelli relativi alle fasi di antropizzazione sono stati utilizzati per realizzare tabelle relative al Valore (V), Vulnerabilità (U) e Pericolosità (H) del territorio. Questi tre parametri sono stati determinanti per definire l'entità della componente geomorfologia del Rischio Ambientale, utilizzato per la pianificazione territoriale in un'area. Per la valutazione del Rischio è stata considerata la relazione R = VUP (UNESCO, 1972), che ha permesso di ottenere un risultato rappresentativo delle caratteristiche delle aree costiere esaminate.

Le due aree prese in considerazione sono state: una *pocket beach* che si estende lungo la costa Adriatica tra i promontori di Torre Canne e Torre San Leonardo, nei pressi di Brindisi ed il tratto costiero ionico nei pressi di Taranto tra Capo San Vito e la Pineta Blandamura.

TERMINI CHIAVE: Geomorfologia, Valutazione dell'Impatto Ambientale, Rischio, Coste della Puglia (Italia).

## INTRODUCTION

Risk is the probability of a loss, and this last one depends on three elements: hazard, vulnerability and value (Crichton, 1999). In the definition of risk, vulnerability plays an important role; generally, it is described as the degree to which a natural system is susceptible to, or incapable to face to, consequences coming from dynamic processes and human impact, including climate variability and extremes (i.e. Gornitz & Kanciruk 1989; Valpreda & *alii*, 2001; Simeoni & *alii*, 2003). The involved parameters could be estimated and combined in comparative dia-

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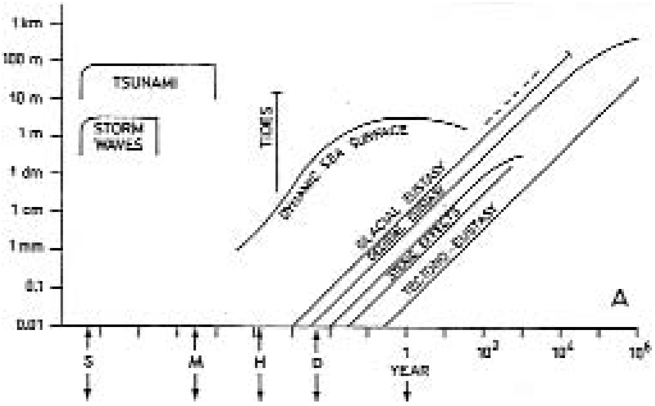


FIG. 1 - The relations between time and amplitude - i.e. rates - of different variables controlling the ocean sea level (Mörner, 1996).

grams (fig. 1) that allow the definition of the reference temporal scale for each specific event (Mörner, 1996).

The aim of this paper is to assess the geomorphologic components of the Environmental Risk caused by hazard events, such as sea storms and tsunamis in two areas: the **B zone** from Torre Canne to Torre San Leonardo Bay (**B**rindisi) and the **T zone** from Capo San Vito to Blandamura Pinewood littoral (**T**aranto) (fig. 2). The choice of these two areas, marked by different morphology, is due to the concentration of tourist-economic activities and the presence of highly preserved natural areas. At present, the environmental dynamics of these areas, such as of the entire coastal area of Puglia region, is characterized by a high instability of the coastal system because of anthropic activity and wave climate as well (Mastronuzzi & *alii*, 2001).

This research has taken into account different elements that influence coastal dynamics: geomorphologic features (geomorphology, morpho-bathymetry, lithology, sedimentology, etc.), meteorological aspects (sea storms intensity and frequency, wave climate, etc.) and land use of the two studied areas.

The methodological concept used for this work is based on a procedure for the evaluation of the Geomorphologic Environmental Risk, defined as «... *probability that economic and social effects get over a certain value about a hazard event*» (Panizza & Piacente, 2003). Therefore, it is necessary to quantify the formula:

Risk (Rg) = Value (V) x Vulnerability (U) x Hazard (Hg)

In general Environmental Risk depends on the summation of the magnitude of different Hazards (H), Vulnerability (U) of the elements exposed to the hazard and on the total Value (V) of the area exposed to the risk

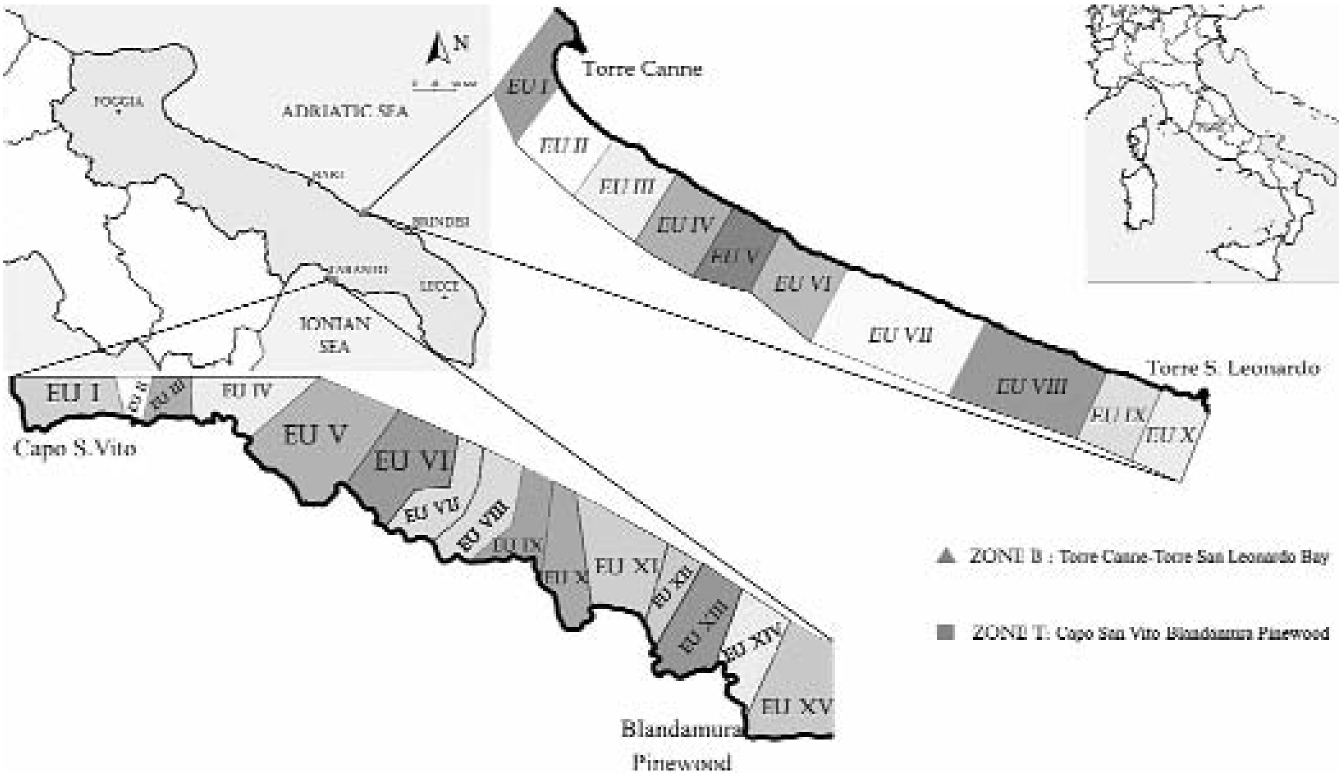


FIG. 2 - Geographical position of studied areas; both areas have been divided in plots (EU), homogenous in features.

(Russo & Valletta, 1995). V is the territory exposed to dangerous phenomena such as human life, civil and tourist buildings, natural and cultivated areas, etc.; U can be defined as the loss of an element of the territory in presence of hazard. H is the probability that a dangerous event occurs with a certain intensity in a certain period. Starting from this formula the Geomorphologic Risk (Rg) can be defined as the loss of human lives, damages to properties, or disruption of economic activities due to a geomorphologic hazard (Hg). A Geomorphologic Risk assessment resulting by sea storms and tsunami has been calculated for each test area.

## MATERIAL AND METHODS

The collected data set referred to the two sampled coastal areas have been used to characterize them and to the Geomorphologic Risk. This evaluation has been carried out using the following procedures:

1. a check - list identifies some coastal parameters known as geo-indicators, since they can supply a description of land development and, in particular, of geomorphologic features (Berger & Iams, 1996; Bush & *alii*, 1999; Simeoni & *alii*, 1999); a numerical value has been assigned to these geo-indicators aiming to assess Value (V) and Vulnerability (U);
2. analysis of marine and climatic conditions using data recorded by the anemometric stations of Ginosa Marina for Taranto Gulf (period between 1968 - 2000), Brindisi-Casale for Torre Canne and Torre San Leonardo (period between 1951-2002);
3. calculation of the *Effective Fetch* using International Map 360 Int 300 «Mediterranean Sea and Black Sea» (published by Marine Hydrographical Institute, 1991);
4. assessment of extreme waves using data from different datasets (NOAA website database, Tinti & Maramai, 1996);
5. reconstruction of wave climate with particular focus on extreme waves;
6. diagrams relative to the coastal evolution of the two sampled areas;
7. a risk table subdivided in Value, Vulnerability and Hazard.

The two investigated areas have been divided in EU (Environmental Unit) on the basis of homogeneous characteristics, according to MaREP project definition (Chemello & Russo, 2001): «*EU is a coastal plot where environmental characteristics, wave movement, bed rock, biological - naturalistic aspects and deterioration of the environment are homogeneous in wide area*». The MaREP project methodology is based on Habitat Evaluation Procedures (HEP) useful to assess the environmental quality and it is used in land management planning along the coast. Geomorphologic Risk has been evaluated comparing EU with the present land use.

The survey of B Zone showed that some areas are completely urbanized, other areas are characterized by the presence of touristic facilities (camping, bathing establishments, etc.) and some others by natural elements (Mediterranean vegetation). The B Zone has been subdivided in 10 EU, with plots stretching perpendicularly to the shoreline. It is possible to recognize only urbanized EU (near Torre Canne and Torre San Leonardo town) or only farm-natural patches (near Lido Morelli). Risk assessment has been calculated giving a subjective coefficient to the most important features of each plot. For example, plots with tourist and civil buildings have been evaluated with high value because of the high number of human lives and the high value of private property (tab. 2a).

In T zone, Value (V) in every EU has been calculated examining 7 categories (human lives number, buildings, military areas, natural areas, bathing establishments, lands and parking areas) selected according to the main features of the area. Vulnerability (U) has been calculated considering typical parameters of this coastal area such as fractures density or cliffs height. At the end, Hazard (Hg) has been calculated on the basis of wind and waves characteristics (tab. 2b).

## MAIN FEATURES OF THE APULIA COAST

The dynamics of Apulia coasts is the result of a system of complex relationships between morphological features, hydrological and oceanographic characters, climatic conditions (Caldara & *alii*, 1998). Apulia region is located in the southernmost part of Italy and part of it is a peninsula which separates the Adriatic from the Ionian sea. The coastal area is characterized by marine landforms such as marine terraces, cliffs, dune belts, sea caves and notches (Mastronuzzi & Sansò, 2002). In particular, two test areas with different geomorphologic features have been selected to assess Geomorphologic Risk. The first one, B zone, is placed near Brindisi, on the Adriatic sea, and it is represented by a pocket beach bordered by a high dune belt that stretches for about 6 km, between Torre Canne and Torre San Leonardo small headlands. The second one, T zone, is near Taranto on the Ionian sea and it is represented by a gentle sloping rocky coast which shelters small pocket beaches (fig. 3).

### *a. - Geological and geomorphologic settings of Torre Canne - Torre San Leonardo Bay (Brindisi) (B zone)*

Torre Canne Bay is placed at the foot of Murge scarp, between Ostuni and Fasano towns, near Brindisi. Along this coastal area Mesozoic and Plio-Pleistocene units are covered by thin bioclastic marine deposits. The local landscape is marked by some wave-cut marine terraces arranged in a flight of stairs stretching from about 65 m of altitude to the present sea level, produced by the superimposition of regional uplift and glacio-eustatic sea level change. Regional geomorphologic evidences sug-

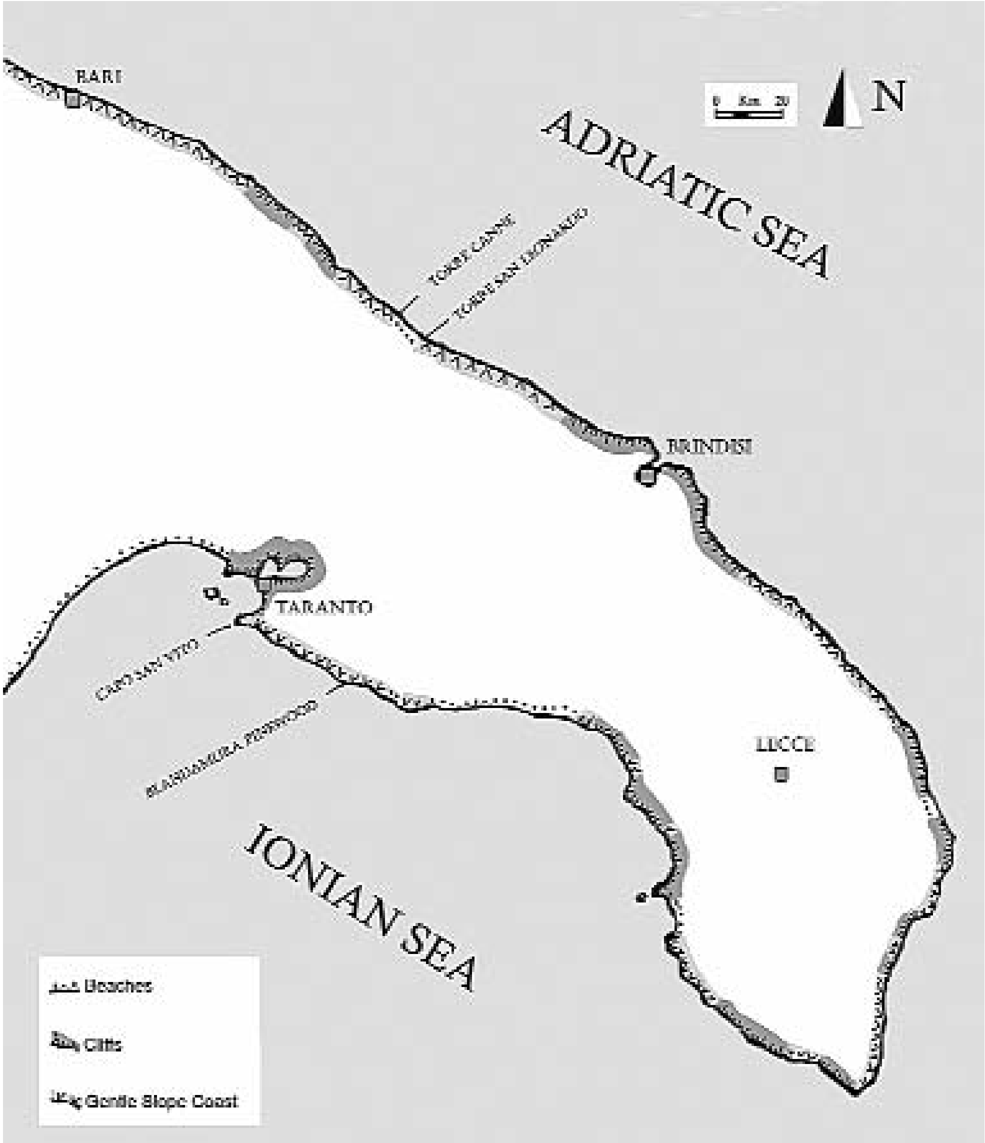


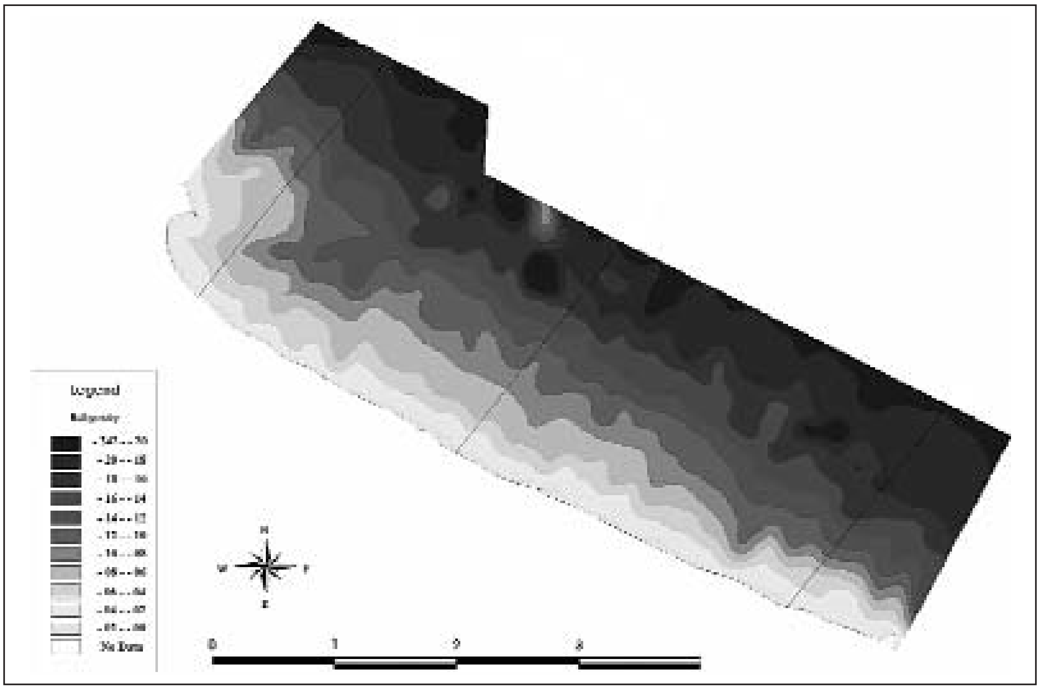
FIG. 3 - Morphological types of coasts; B Zone and T Zone are the investigated areas.

gest that the formation of these terraces most likely occurred during Middle-Upper Pleistocene high sea level stands, even if no absolute ages determination is available yet. The monotony of the coastal landscape is interrupted by a relict drainage network made of deep sapping valleys, locally named *lame*, which dissect the entire terrace sequence (Mastronuzzi & Sansò, 2002). Beach sediments are bioclastic debris and material comes from the intense erosion of rocky promontory and coastal dunes. Morphologically B Zone is defined by two rocky promontories that have formed a «trap» system for sediments determining a *pocket beach*. The overlap of different generations of aeolian deposits (Mastronuzzi & Sansò, 2002) produced a quite continuous dune belt elongated in NW-SE direction, about parallel to shoreline and with maximum height of 10 m in the middle-southern part of the bay. The area behind the dune belts is filled by sand-clay colluvial sediments with maximum thickness of 10 m. A wide aquifer rests on sea water intruded from the coast.

### *a.1 - Morpho-bathymetric map*

A morpho-bathymetric map has been obtained using the nautical maps in 1:40000 scale and the software Surfer 7.0 (fig. 4). The map shows the smooth morphology of sea bottom with isobaths parallel to the coastline. Bathymetric contour lines indicate a steeper slope in front of Torre San Leonardo than at Torre Canne town. However, it is possible to detect some breaks-in-slope; the most important of them is located to south-east of the Torre Canne harbour with major axis orientated to east-west.

FIG. 4 - Morphobathymetric map of B Zone.



*b. - Geological and geomorphologic settings of Capo San Vito - Blandamura Pinewood area (Taranto) (T zone)*

Taranto is located to the south-western part of Apulia along the Ionian coast. In this area the Mesozoic carbonate basement is dislocated by NW-SE faults into a step-like arranged blocks dipping from the Murge plateau towards both Ionian sea and Bradanic foredeep. The Mesozoic limestones are covered by a sequence composed by the Calcareniti di Gravina formation (Upper Pliocene) passing upward into the Argille Subappennine (Middle Pliocene-Lower Pleistocene). In particular, along the investigated coast stretching between Capo S. Vito and Blandamura Pinewood (South of Taranto Gulf), marine terraced deposits referable to the last Interglacial period (MIS 5) overlie the clay (i.e.: Belluomini & *alii*, 2002). The investigated coastal area is characterised by the absence of an active drainage network.

The local stratigraphic sequence of the area is exposed along cliffs face (maximum height 6 m) and it is characterized by marine sandy clays at the bottom and calcarenites at the top (fig. 5). In the coastal area, the high frequency of sub-vertical longitudinal and transverse fractures influence cliff evolution influenced by rock properties and the effects of sea storms on the basal clays. They determine a high risk of collapse: an example is «Grottaglia» site (EU IX) where there is a high frequency of collapses.

The shoreline of investigated area is irregular with a retreat rate extremely low (0.06 m/y - 0.8 m/y), and it is characterized by a large number of inlets where pocket beaches usually develop. The most important bathhouse occurring along this coast are Sun Bay, Lido Bruno, Saint-Bon, Tramontone and Mon-Rêve. These beaches are continuously in evolution, with a sediment input represented

FIG. 5 - Cliff in Battaglia zone near Taranto; it is possible to observe a detaching niche of a recent collapse and the local stratigraphic sequence: 1) soil about 90 cm thick covered by *gariga*; 2) Raised beach (Upper Pleistocene) (thickness: 1,3 m); 3) Argille subapppennine (Late and Middle Pleistocene) (thickness between 6-8 m).

mainly by biogenic material and, subordinately, by material coming from cliff retreat.

### *b.1 - Morpho-bathymetric map*

Sea bottom morphology has been deduced by nautical maps analysis in 1:40000 scale published by Istituto Idrografico della Marina. Collected data have been used to build a three-dimensional models of depth based a bathymetric data grid and elaborated using Surfer 7.0 software (fig. 6).

The sea bottom between 0 and –20 m in depth is characterised by low slopes shaped on algal limestone similar to those cropping out along the coastline.

## MARINE CLIMATIC ASPECTS

### TORRE CANNE (BRINDISI)

Wind-wave aspects of the B Zone have been evaluated (sea storms, wave forecasting, wind analysis, etc.) using synoptical tri-hour records furnished by Meteorological National Service Military (ITAV) of the Brindisi-Casale weather station from 1951 to 2002 period. An elaboration phase (mean value, percentage attendance, etc.) with Microsoft Excel electronic calculation has been executed. Coastal dynamics of the southern Adriatic sea is influenced by northern winds: the Tramontana wind initially comes from North and then changes to NW in proximity of the Gargano Promontory and with this direction it reaches the shoreline. Excluding wind zero periods with 17,2% frequency, Mistral wind has 16,8% frequency, Sirocco wind 15,2% and Tramontana wind 14,8% (fig. 7).

Beaufort Scale shows wind intensity classes from 0 to 12 Beaufort. For each class, the number of the records corresponding to relative intensity wind has been evaluated, for the entire period. Only classes between 4 to 12 have been considered because they could cause detectable shoreline change. The elaboration shows that during the last 20 years sea storms decreased.

Using the elaborated wind data, wave features (wave height H, period T, length L) have been calculated. Obtained data have been put in hind-casting automatic models; these ones are represented by empirical graphs showing correlation between wind and waves.

In south Adriatic coast the waves come from N160 with 17% in frequency and from N290 with 8% in frequency. The highest waves come from N240 but they are concentrated on the average between N130 and N320 with maximum height of 4.5 meters.

### TARANTO

Wind analysis of coastal area (T Zone) has been possible screening the data recorded in Ginosa Marina weather station during a period from 01/01/1968 to 31/12/2000. According to statistical data elaboration, Mistral is prevailing wind with average frequency of 29.42% and an effective fetch of 15.46 mn, while Sirocco is dominant wind with average frequency of 12.77% and effective fetch of 637.82 mn (fig. 8).

Wind events have been calculated on the basis of 12 intensity classes suggested in the Beaufort scale: it is important to stress the increasing trend of extreme events during the last 15 years.

In the investigated area, the *traversia sector* can be defined as the angle including all directions from those the wind causes significant waves.

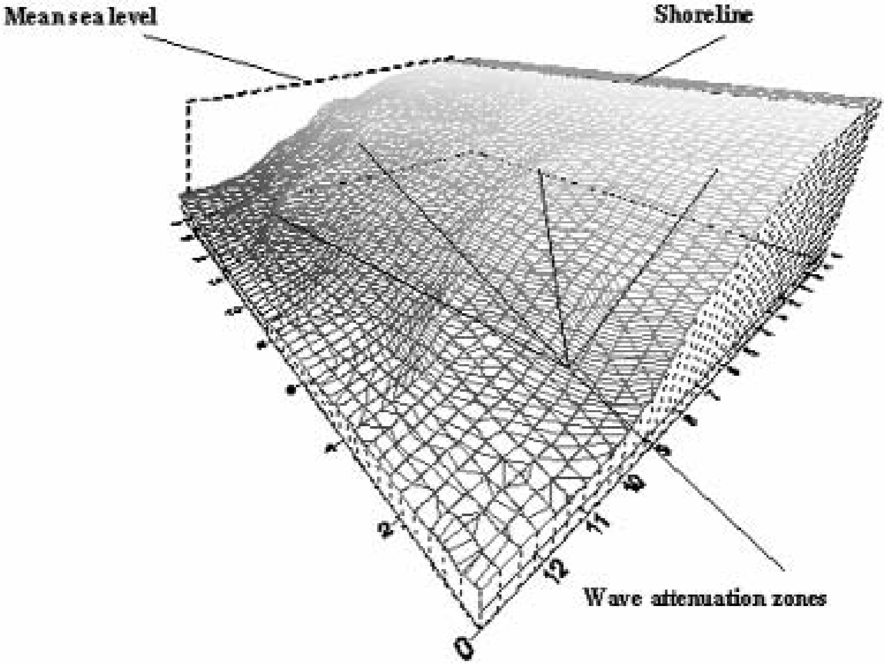


FIG. 6 - 3D model showing bathymetric characteristics of T Zone.

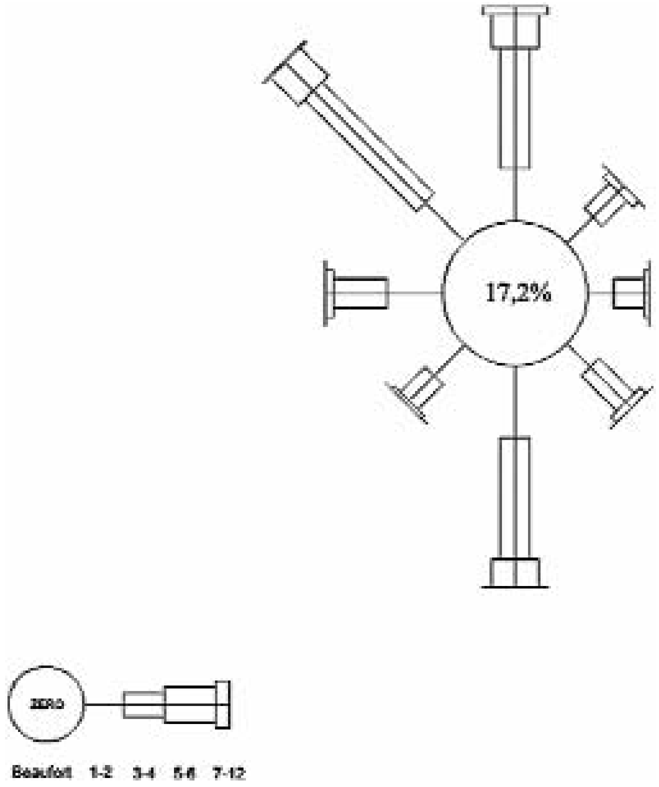


FIG. 7 - Beaufort graph shows the annual wind trend of the Brindisi-Casale weather station between 1951-2002 period.

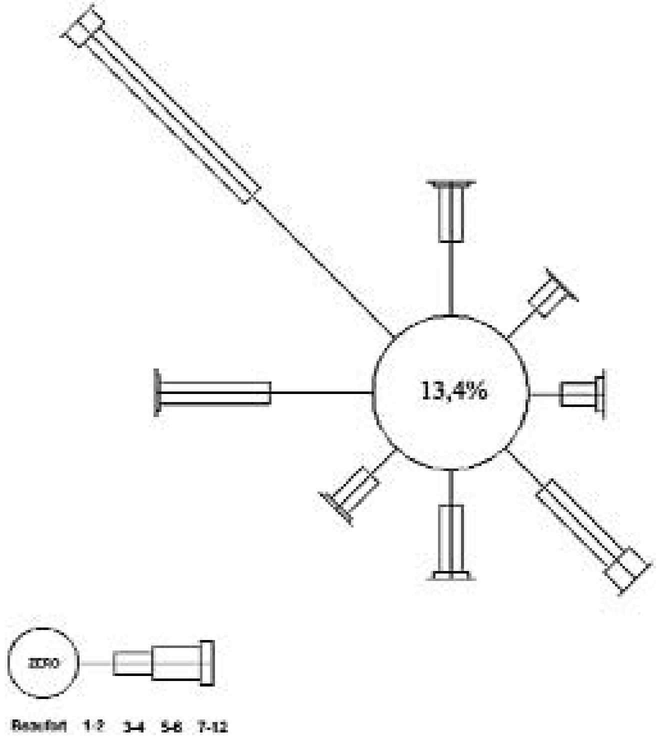


FIG. 8 - Beaufort graph indicates the annual wind trend of the Ginosa Marina (Taranto) weather station between 1968-2000 period.

Regarding extreme cases analysis, it has been possible to estimate wave parameters (wave height $Hs_0$ and period $Tp_0$) in this area. In particular, waves characteristics have been defined for extreme events (parameters are in tab. 1) and to the frontal wave evolution near the coast, both with Tenani method (1952) and S.M.B. method (C.E.R.C., 1984), has been elaborated. The frontal waves near coast, during main sea storms, have a weakening at 20 m depth (at a distance from coast of 750 m) with a speed decrease of 2,94 m/s, and this determine a 7,6 rotation degree. So, the areas where erosion processes are evident have been identified; dissipation wave movement along this coast has been calculated.

TABLE 1 - Typical parameters of the wave action referred to two main sea storm; where $Hs_0$ is a offshore wave height in m; $Tp_0$ offshore wave period (sec.); $L_0$ offshore wave length (m); $d_{lim}$ boundary bathymetric contour line (m): it is the depth where the waves interact with bottom producing refraction effects; $C_0$ offshore wave velocity (m/sec); ai angle between offshore bathymetric contour line and wave front (grad).

| *Wind Direction (N)* | *$Hs_0$ (m)* | *$Tp_0$ (s)* | *$L_0$ (m)* | *$d_{lim}$ (m)* | *$C_0$ (m/s)* | *$a_i$ (grad)* |
|---|---|---|---|---|---|---|
| *120* | *0,25* | *11.01* | *192.46.00* | *96.23.00* | *17.34* | *35* |
| *140* | *0,260417* | *9.53* | *141.68* | *70.84* | *0,64375* | *35* |

## LAND USE MAP

A land use map has been elaborated in order to highlight the features of studied area, such as geomorphology and/or influence of men in the environment development. The map has been carried out by adopting the «technical» land use classification introduced by Panizza & Piacente (2003) and that one relative to the territory evaluation, which includes social-economic aspects.

For B Zone, the land use map has been realized in four phases:
1. aerial photos analysis;
2. topographic survey;
3. bibliographic and experimental data elaboration;
4. map realisation by GIS.

In the first phase, two aerial photos (of 1954 and 1975) have been examined. They put in evidence anthropic impact in coastal evolution. In fact, in the 1954 aerial photo the landscape was not urbanized; there weren't important road networks and the beaches were still very wide. The 1975 aerial photo evidences the new road network, the harbour structures in Torre Canne, and the farm and urban areas in Torre Canne bay. Using Regional Technical Map (CTR) 1:5000 of the Torre Canne - Torre San Leonardo Bay, the land use map showing also farm and naturalistic areas (fig. 9a) has been made.

For T Zone the land use map has been realized with:
1. topographic surveys;
2. bibliographic and experimental data elaboration;
3. evaluation map with AutoCad software.

Data were translated into a detailed land use map of Taranto area, originally in scale 1:5000 (fig. 9b).

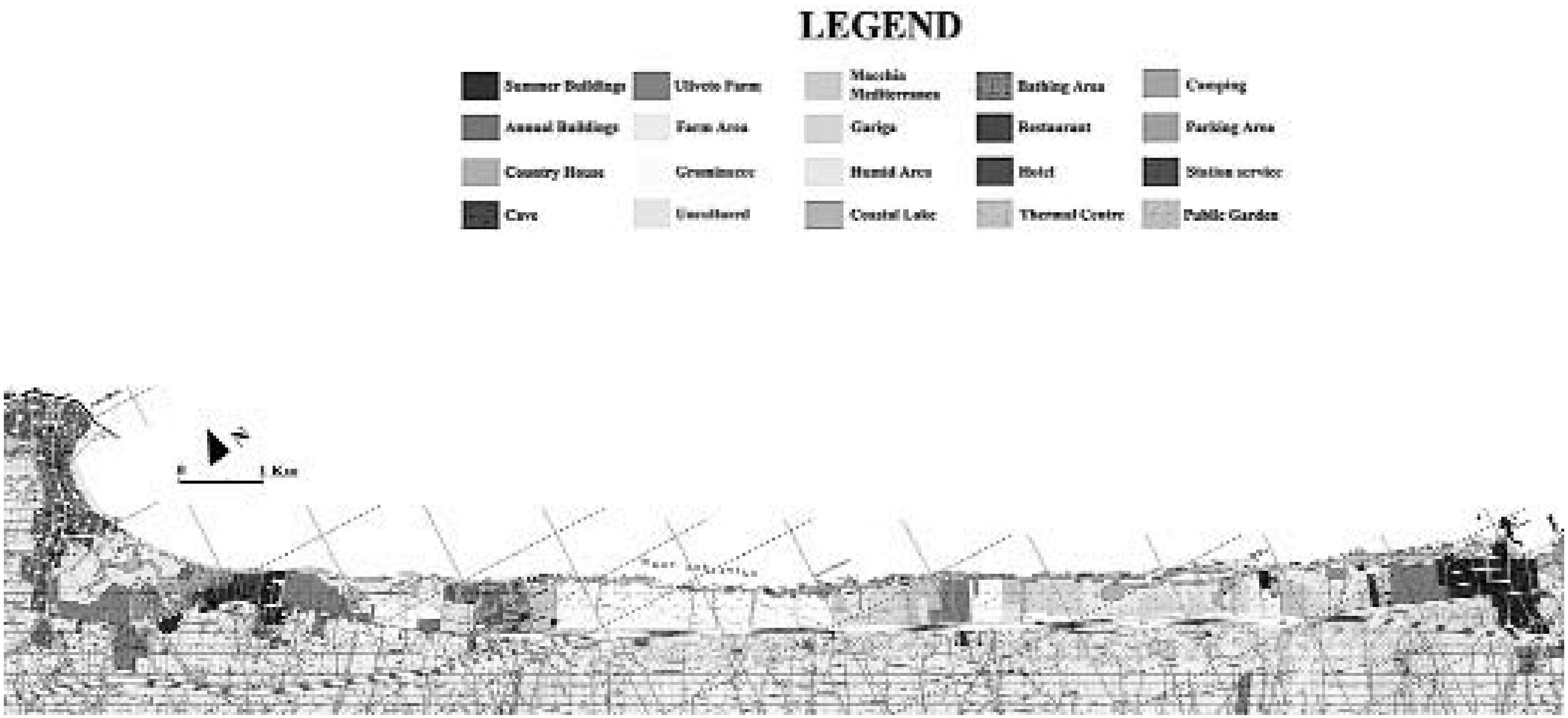


FIG. 9a - Land Use Map elaborated to show table 2a results.

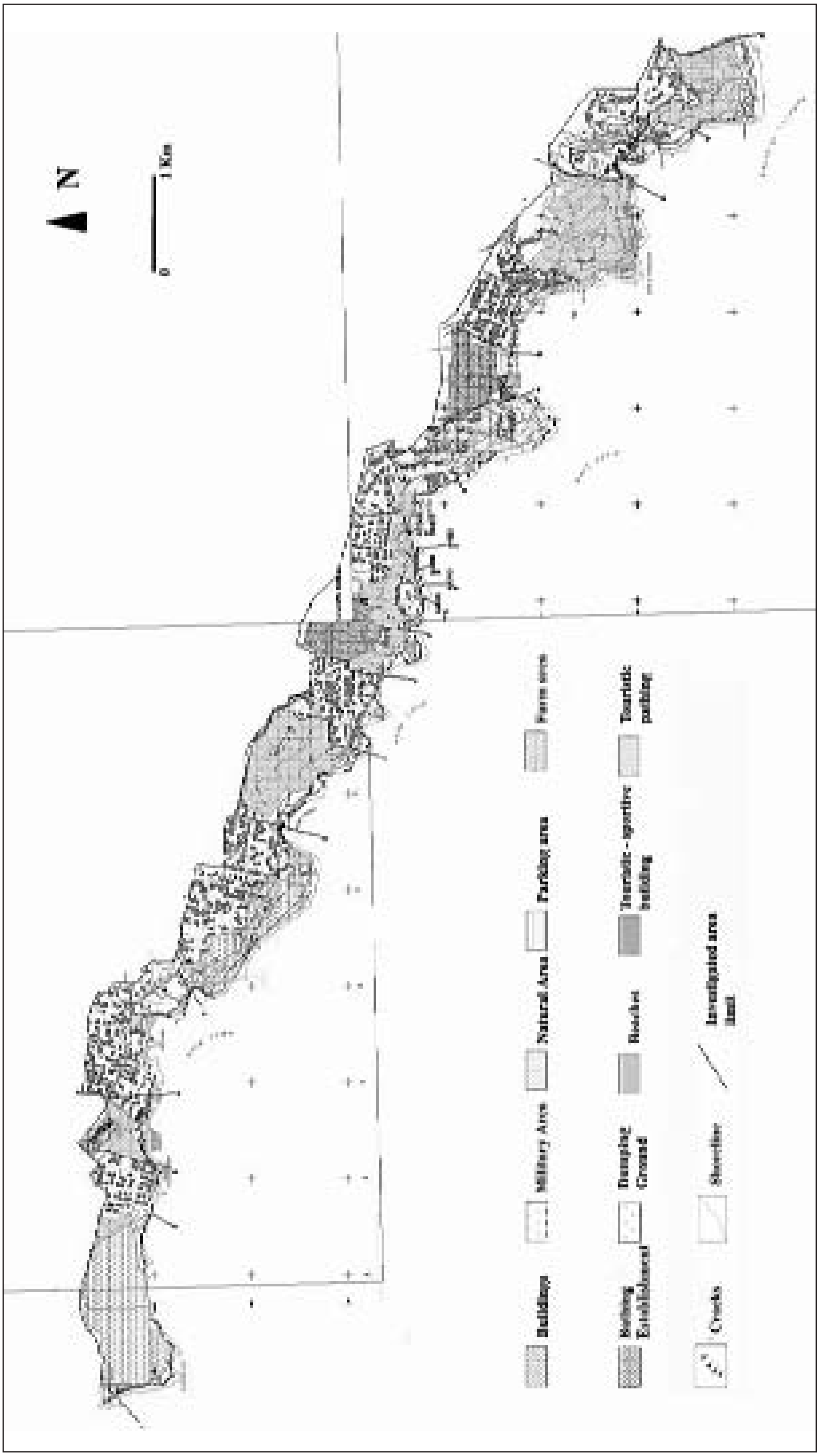


FIG. 9b - Land Use Map elaborated to show table 2b results.

## GEOMORPHOLOGIC - ENVIRONMENTAL RISK

Geomorphologic - Environmental risk is defined as: «a result of sum up of partial evaluations of one or more risk elements characterizing several features of the environment system» (Russo & Valletta, 1995). Value (V), Vulnerability (U) and Natural Hazard (Hg) are the three parameters that determine the «equation» of Risk and describe coastal features.

### *a.1 - Coastal area Value*

Different approaches have been applied to calculate Value for each EU in both areas. After surveys, the two investigated areas show different geo-environmental features and human impact that have permitted to identify several Value elements.

The area, in hectares, for each EU (subdividing into Farm and Productive Use Area, Civil and Tourist Buildings and Natural Area) has been measured during surveys. N° Human Lives has been estimated both in winter and summer period and a mean value has been assigned. Comparing all the values calculated for each EU in B Zone, it has been possible to obtain a T coefficient (Total) between 0 (low value of the territory) and 10 (high value of the territory).

For each EU, in T Zone, some categories (N° Human Lives, Civil building - Tourist - Sports, Military Areas, Natural Areas, Parking Areas, Cultivated Land, Bathing Establishments) have been examined. At first a number N, between 0 (minimum considered value) and 10 (maximum considered value), has been allotted - founded on classes importance - both in winter and summer period. N has an objective value (indicated as value 1) and it has been compared to a subjective value (indicated as value 2), obtained multiplying N to a factor (subjective) suitably chosen for all classes. Final Value (V) for the Geomorphologic - Environmental Risk estimated has been «corrected» balancing the two values (value 1 and 2) with elaborated land use map.

### *a.2 - Coastal area Vulnerability (U)*

Vulnerability of the B Zone is characterized by seven different parameters: Length, Width, Altitude dimension of the dune belts, Number and Wideness of the dune gaps, Distance (DSAH) from shoreline of the area exposed to hazards. All parameters have been measured and carried out in a table wherewith an overall Vulnerability has been calculated for each EU.

Surveys have permitted to evaluate vulnerability (U) of T Zone considering seven parameters to describe site geomorphologic features: rocky coast wideness, pocket beaches wideness, cracks transverse number, cracks longitudinal number, cliffs height, boulders weight, boulders distance from shoreline. Field data have been related to final factor that quantified Vulnerability for every EU.

### *a.3 - Coastal area Hazard (Hg)*

Hazard coast has been estimated considering two elements: storm surge and tsunami. To evaluate these elements historical occurrences have been collected from local reports, Italian catalogue that includes events occurred in Italian seas (Tinti & Maramai, 1996) and tsunami database in NOAA (National Oceanic and Atmospheric Administration, USA) website has been examined. All collected data have been elaborated by statistical method. Both investigated sites have a low tsunami danger (0,03% for every EU in B Zone and 0.184% for every 15 EU in T Zone). Nevertheless, these extreme events should be considered since morphologic evidences of historical tsunami have been detected on the Apulia coast (Mastronuzzi & Sansò, 2002).

Wind analysis in B Zone has been based on anemometric data elaboration of the last 50 years, in particular, the number of the hazardous events has been calculated for each recorded year. Furthermore, each sea storm had a certain mean duration by which three different kinds of hazard have been detected:

- **mean hazard** is related to the percentage of sea storms with wind intensity between 11 and 24 knots and wind duration of 44 hours;
- **high hazard** is related to the percentage of sea storms with wind intensity between 25 and 47 knots and wind duration of 7 hours;
- **exceptional hazard** is related to the percentage of sea storms with wind intensity between 48 knots and more and wind duration of 3 hours.

In the case Torre Canne Bay, the sea storm hazard is related to waves propagating from N-NE, from E and from W-NW.

Using anemometric data of Ginosa Marina weather station between 1968 and 2000, hazardous events number has been calculated relating to waves produced by wind with speed intensity major or equal to 35 nautical miles for every year. Three different classes of hazard have been identified in function of time period event:

- **mean hazard** correlated to swells with intensity major or equal to 35 nautical miles and a maximum time period of 3 hours;
- **high hazard** correlated to swells with intensity major or equal to 35 nautical miles and maximum time period of 6 hours;
- **exceptional hazard** correlated to swells with intensity major or equal to 35 nautical miles and maximum time period of 9 hours and more.

The collected data show that in the T zone winds blowing from North, North-East and East directions do not produce effects on coastal dynamics whereas S, SE, SW and NW winds are important to define hazard percentage.

## GEOMORPHOLOGICAL-ENVIRONMENTAL RISK ASSESSMENT

The analysis of geomorphologic, weather-marine and landscape features allowed to assess the obtain Geomorphological-Environmental Risk value along the coast between Capo San Vito and Blandamura Pinewood (table 2b; fig. 9b). The study of coastal dynamics suggests that exceptional sea-storms have significant effects on coastal evolution even if their frequency decreased during last years.

Some areas are more exposed to risk than others because of inappropriate land use that modified environment dynamics and of an economic development related to the growing tourist industry as well.

Torre Canne-Torre San Leonardo Bay (table 2a; fig. 9a) shows some EU affected by higher risk than others. EU 9 has the maximum score of the environmental risk about 640; this is due to the high V value because it includes a thermal buildings and tourist facilities. Here, natural barrier, especially dune belt, doesn't assure stability and protection to the coastline affected by frequent Tramontana sea storms. The second place is occupied by Torre Canne town (EU 10); this area is characterized by the absence of natural protection, substituted by insufficient breakwater, and high concentration of human lives. Torre Canne is relatively protected from N and NW sea storms by harbour structures; however, EU 10 isn't preserved by Levant sea storms, which are less frequent but more severe. Along this EU some houses have been directly built on the beach. EU 7 is absolutely deprives of natural and anthropic protection but it is frequented by tourists. EU 2 has minor score of the environmental risk due to the presence of a very large sandy beach, about 34 m wide, backed by a high dune belt. EU 1, 3 and 5 have almost the same risk score due to the combination of each element of the risk. For example, EU 5 has low vulnerability and low value but it has the same score risk comparing to EU 1, very vulnerable because of houses presence.

In Taranto area, the EU 4, indicated as «Lido Bruno», shows the major Environmental Risk due to the high Hazard and Vulnerability (10) and a low Value (7). This high Risk value is due to the presence of cliffs (about 6 m in height) that show a high percentage of longitudinal and transversal fractures and is rapidly retreating because of a large number of rock falls.

EU number 5, indicated as «Battaglia», is the second unit (score 630) due to high Value (9) and Hazard (10) along with low Vulnerability (7).

EU number 9, indicated as «Grottaglia», has a risk equal to 560.

EU number 1, 7 and 12 have a risk between 336 and 432 because of residential and military buildings (and so a high number of human lives) presence near coast. In these areas an exceptional event could have significant effects because of proper protections absence. EU number 6, 10, 11 and 15 are homogenous with lowest risk between 84 and 42. Finally, EU number 2, 3, 8, 13 and 14 have a risk between 112 and 280.

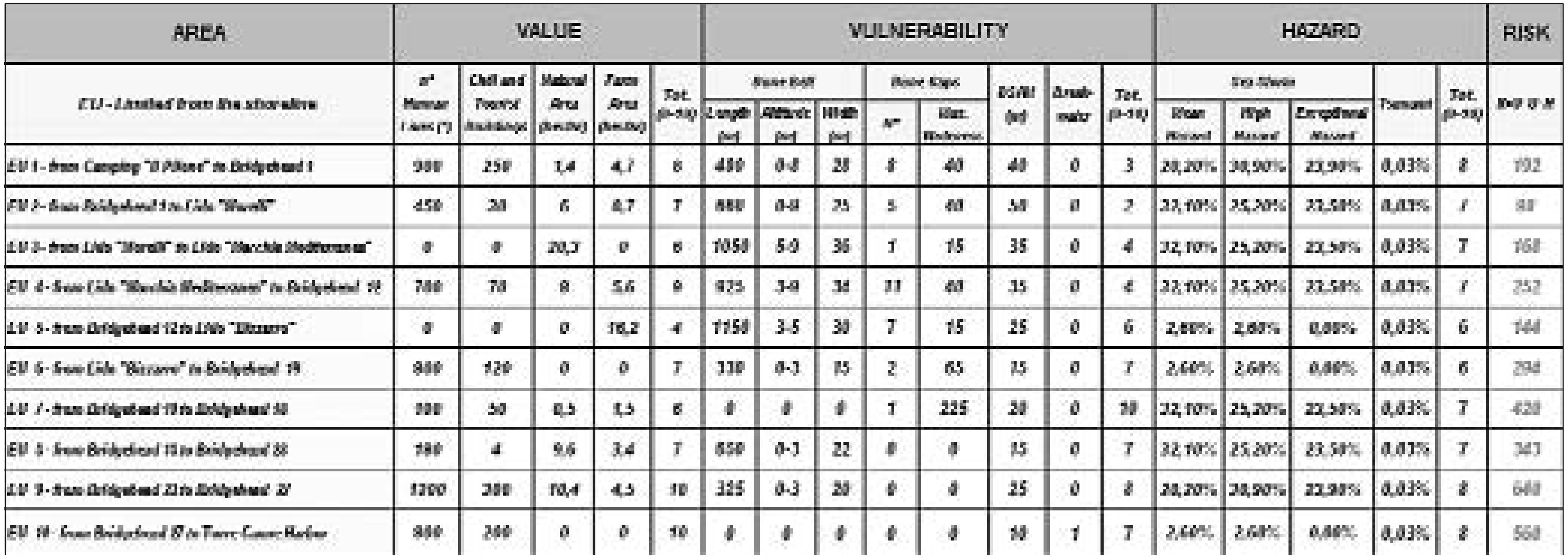
## CONCLUSIONS

This study has been executed in order to obtain an evaluation of geomorphologic risk of the Apulia coast. A whole data, pertinent main environmental characteristics of the two test areas, has been collected during numerous surveys. An analytic method based on the utilization of mathematical matrix has been applied to calculate risk elements (vulnerability, value, hazard). Each matrix is constituted by some row vectors, obtained by subdivision of test areas in plots, and some column vectors that represents the balance of the risk elements analysed. This methodology has showed advantages for the integrated evaluation of the coastal elements relating to hazardous elements, natural or due to human activities; furthermore, this methodology has simplified the management of flexibility of the calculation (Simeoni & *alii*, 2003). The results show clearly that some plots have a major risk than others because human influence has conditioned coastal natural dynamic and land value has been increased by economical tourism. Risk increase is due to also the unexpected sea level rise that could be heavy relating to geomorphologic features (absence and/or damages to dune belt, gentle slope rocky coast or cliffs with lithologic series incoherent at the base). Furthermore, in a pressured environment sea storm and tsunami could occur in short time because the released energy is high in the temporal unit (Bruun, 1962).

The study of the environmental and geomorphologic features jointly to winds statistics allowed to understand the main characteristics of coastal systems and the links between environment and human activities. So the territorial planning isn't a simple urban project to realize buildings but it must include land use capability and relations between man and environment. In relation to this, the CEE 85/337 rule introduced Environmental Impact Assessment (E.I.A.) in order to evaluate factors to measure direct and indirect impacts, in a short and long time, individual and many impacts, positive and negative impacts, that some human actions should generate in environment, in a specific area.

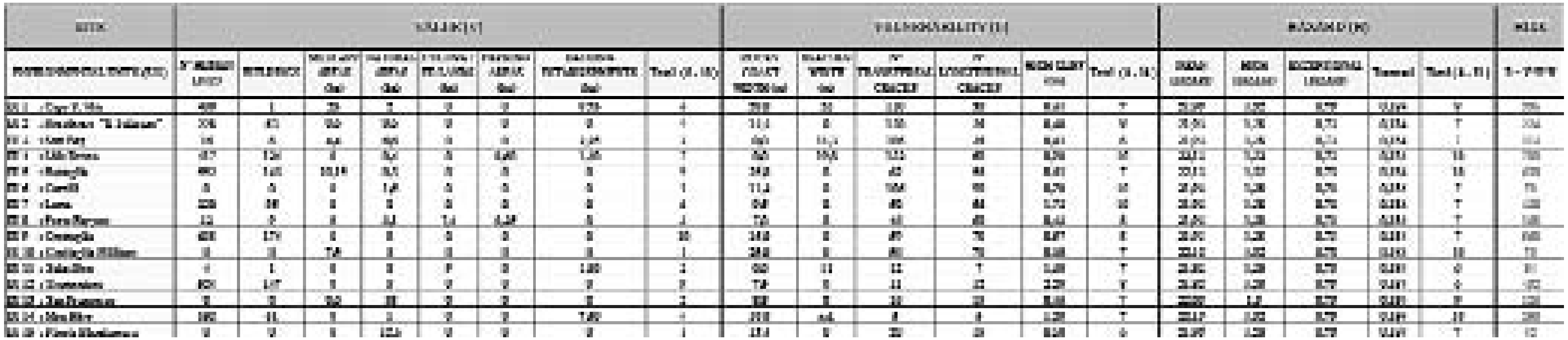
Environmental Impact Assessment (E.I.A.) is characterized by a preliminary study, the environmental impact study (E.I.S.) that consists of three reference spheres (planning, programming and environmental): so E.I.A. identifies areas more vulnerable than others and so riskier. The landscape preservation must not be in conflict to natural equilibrium of the ecosystem and the economic value of the areas. This study should suggest a series of actions to rebuilt and to revalue the environment: for example the collaboration between more scientific groups will let the selection of EU, with a typical scientific and/or cultural interest, which will be named «Geo-site».

TABLE 2a - Table shows the morphodynamic Risk Assessment (Russo & Valletta, 1995) along the coast of Brindisi (Apulia, Italy). In the first field are showed the value elements (number of human life, buildings-residence civil and touristic, natural area, farm area) with the corresponding scores to each EU; in the second field are showed the vulnerability elements (dune belt, dune gaps, DSAH, break-weather) with the corresponding scores to each EU; in the third one are showed the hazard elements with the corresponding score in % to each EU.



| AREA | VALUE | | | | | VULNERABILITY | | | | | | | | HAZARD | | | | | RISK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Dune Belt | | | Dune Gaps | | | | | Sea Storm | | | | | |
| EU - Limited from the shoreline | n° Human Lives (*) | Civil and Tourist Buildings | Natural Area | Farm Area | Tot. (0-10) | Length (m) | Altitude (m) | Width (m) | n° | Max. Wideness | DSAH (m) | Break-water | Tot. (0-10) | Mean Hazard | High Hazard | Exceptional Hazard | Tsunami | Tot. (0-10) | R=V·V·H |
| EU 1 - from Camping "Il Pilone" to Bridgehead 1 | 900 | 250 | 1,4 | 4,7 | 8 | 480 | 0-8 | 28 | 8 | 40 | 40 | 0 | 3 | 28,20% | 38,90% | 23,90% | 0,03% | 8 | 192 |
| EU 2 - from Bridgehead 1 to Lido "Morelli" | 450 | 20 | 6 | 6,7 | 7 | 880 | 0-8 | 25 | 5 | 60 | 50 | 0 | 2 | 32,10% | 25,20% | 23,50% | 0,03% | 7 | 98 |
| EU 3 - from Lido "Morelli" to Lido "Macchia Mediterranea" | 0 | 0 | 20,7 | 0 | 6 | 1050 | 5-0 | 36 | 1 | 15 | 35 | 0 | 4 | 32,10% | 25,20% | 23,50% | 0,03% | 7 | 168 |
| EU 4 - from Lido "Macchia Mediterranea" to Bridgehead 12 | 700 | 70 | 8 | 5,6 | 9 | 925 | 3-8 | 34 | 11 | 60 | 35 | 0 | 4 | 32,10% | 25,20% | 23,50% | 0,03% | 7 | 252 |
| EU 5 - from Bridgehead 12 to Lido "Bizzarro" | 0 | 0 | 0 | 16,2 | 4 | 1150 | 3-5 | 30 | 7 | 15 | 25 | 0 | 6 | 2,80% | 2,60% | 0,00% | 0,03% | 6 | 144 |
| EU 6 - from Lido "Bizzarro" to Bridgehead 19 | 800 | 120 | 0 | 0 | 7 | 330 | 0-3 | 15 | 2 | 65 | 15 | 0 | 7 | 2,60% | 2,60% | 0,00% | 0,03% | 6 | 294 |
| EU 7 - from Bridgehead 19 to Bridgehead 50 | 900 | 50 | 0,5 | 1,5 | 6 | 0 | 0 | 0 | 1 | 225 | 20 | 0 | 10 | 32,10% | 25,20% | 23,50% | 0,03% | 7 | 420 |
| EU 8 - from Bridgehead 15 to Bridgehead 88 | 700 | 4 | 9,6 | 3,4 | 7 | 650 | 0-3 | 22 | 0 | 0 | 15 | 0 | 7 | 32,10% | 25,20% | 23,50% | 0,03% | 7 | 343 |
| EU 9 - from Bridgehead 23 to Bridgehead 27 | 1200 | 300 | 10,4 | 4,5 | 10 | 325 | 0-3 | 20 | 0 | 0 | 25 | 0 | 8 | 28,20% | 38,90% | 23,90% | 0,03% | 8 | 640 |
| EU 10 - from Bridgehead 37 to Torre Canne Harbor | 800 | 200 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 1 | 7 | 2,60% | 2,60% | 0,00% | 0,03% | 8 | 560 |

TABLE 2b - Table shows the morpho-dynamic Risk Assessment (Russo & Valletta, 1995) along the rocky coast of Taranto (Apulia, Italy). In the first field are showed the value elements (number of human life, buildings-civil residence and touristic, military area, natural area, parking area, farm field, bathing area) with the corresponding scores to each EU; in the second field are showed the vulnerability elements (rocky coast width, beaches width, number of cross sheet fractures, number of longitudinal fractures, cliff height) with the corresponding scores to each EU; in the third field are showed the hazard elements with the corresponding score in % to each EU.



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