Coastal Buffer Zones in Taiwan

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Keywords: coastal buffer zone ; coastal disasters ; impact factors

1. Definition of the Coastal Buffer Zone

The terms buffer zone, buffer region, or buffer strip are used mostly in the context of rivers, ecology, and environmental conservation [1][2][3][4][5][6][7]. Although there are relatively few reports and studies on actual coastal performance, the functional mechanisms applicable to inland riparian buffer zones can also be applied to coastal buffer zones for achieving a better balance between coastal resource protection and development [8].

The coastal buffer zone is the transition area between land and sea spaces, encompassing lagoons and intertidal zones. Since there is no clear universal definition of the coastal buffer zone, scholars in different professional fields of science, biology, and physics have proposed diverse definitions of the coastal buffer zone. For instance, in the field of marine physics, the coastal buffer zone is the region between the nearshore and ocean currents, as shown in **Figure 1** [9]. Kuo and Chang [10] introduced coastal buffer zones based on marine ecology and environmental science. According to them, the coastal buffer zone extends from the waterline between the ocean and the land to a depth of 20 or 30 m in the sea, where underwater plants can photosynthesize. According to the waterline conditions that can be reached by waves and tides, the coastal buffer zone can be divided into three parts (**Figure 2**): the area reachable by waves is called the supratidal zone; the area between the high tide line and the low tide line is called the intertidal zone; and the area below the low tide line is called the subtidal zone. In addition, according to Park et al. [11], the characteristics of the groundwater level can be used to establish coastal buffer zones on natural beaches.

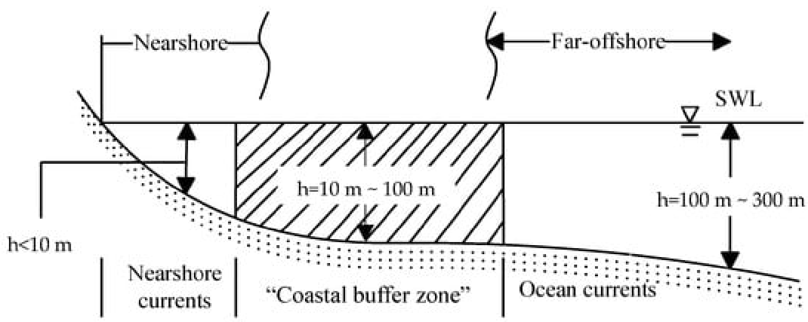

Figure 1. Definition of coastal buffer zone based on marine physics [9].

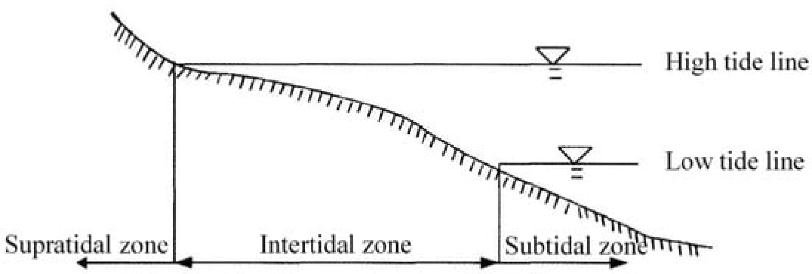

Figure 2. Definition of coastal buffer zone based on marine ecology and environmental science [10].

Therefore, to establish a clear, universal definition of the coastal buffer zone, collaboration among relevant experts and governments is essential. The experts from various parties and relevant government agencies in Taiwan were invited to discuss and reach a consensus. Accordingly, the coastal buffer zone can be defined from two perspectives: disaster prevention and coastal protection [12]:

1.1. Definition from the perspectives of coastal dynamic systems and processes

In terms of its land part, the coastal buffer zone should be defined as the area that can be reached by seawater. The broad definition should include coastal flooding areas by typhoons and storm surges. In the water part of the coastal buffer zone, areas with obvious sediment drift and transport should be included. The narrow limit can be set within the range of significant nearshore currents (water depth of 5–10 m), and the broad limit can be extended to the range where tidal currents affect sediment drifting (water depth of 20–30 m or deeper);

1.2. Definition from the perspective of disaster prevention

The coastal buffer zone can be defined as the region where the coastal disasters (such as typhoon wave height, storm surge, or nearshore currents) are reduced or eliminated. The range of this buffer zone can only include sea or land areas.

In the face of sea level rise and other severe coastal disasters as a result of climate change, we believe that it is appropriate to define the coastal buffer and protection zone from the perspective of disaster prevention and protection. Therefore, we adopted the following definitions to establish the coastal protection and buffer zones (**Figure 3**):

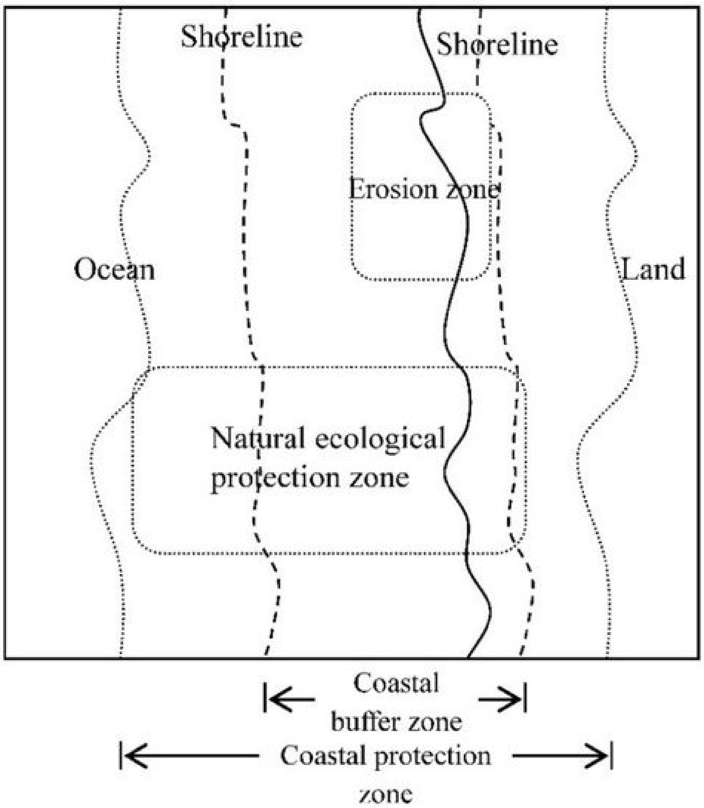

Figure 3. Sketch of coastal buffer and protection zones.

- Coastal protection zone:

➢Aspect of land basin: area where coastal flooding may occur due to typhoons or storm surges;
➢Aspect of ocean area: the farthest range of sediment drift induced by tidal currents.

- Coastal buffer zone:

➢Aspect of land basin: the area that may be reached directly by seawater due to typhoons or storm surges, or that presents buffering factors to minimize the occurrence of disasters;
➢Aspect of ocean area: the farthest range of sediment drift induced by nearshore currents, or the area that presents buffering factors to minimize the occurrence of disasters.

In Taiwan, the designation of coastal protection and buffer zones is based on typhoon waves and their resultant storm surges during a return period of 50 years as the input conditions. The suitability of the designated area is reviewed every ten years.

2. Recommendations for the Management and Administration of Coastal

Buffer Zones

The planning and management of coastal buffer zones can be divided into two spatial directions, namely, land and nearshore sea areas, and then further combined into the entire strip. In addition to coastline and surface protection, research in the entire region must focus on coastal ecology, disaster prevention, and landscape recreation (**Figure 4**) [13]. Therefore, the concerned issues of coastal buffer zones must involve three aspects: technology, planning and management, and policy-making.

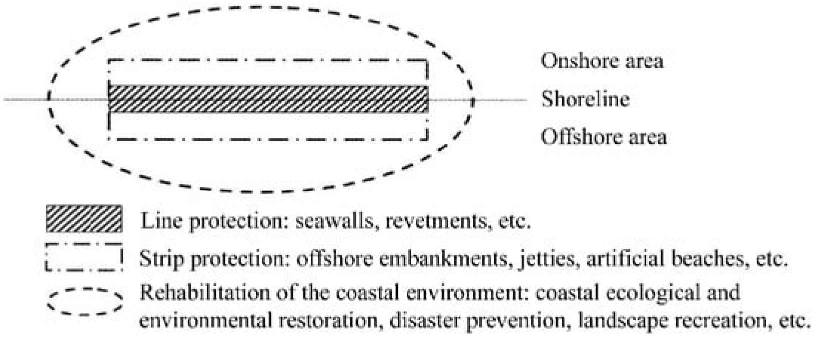

Figure 4. Research direction for coastal buffer zone management [13].

2.1. Aspect of Technology

Applying relevant research technologies to understand the characteristics of the impact factors of coastal buffer zones and their effects in preventing waves, reducing tidal currents, or delaying tidal waves from attacking natural or artificial structures is essential to ensure the sustainable use of coastal buffer zones. According to the basic definition of the coastal buffer zone proposed in the present study, the impact factors of the coastal buffer zone can be divided into two parts: natural and anthropogenic impact factors (**Figure 5**) [14].

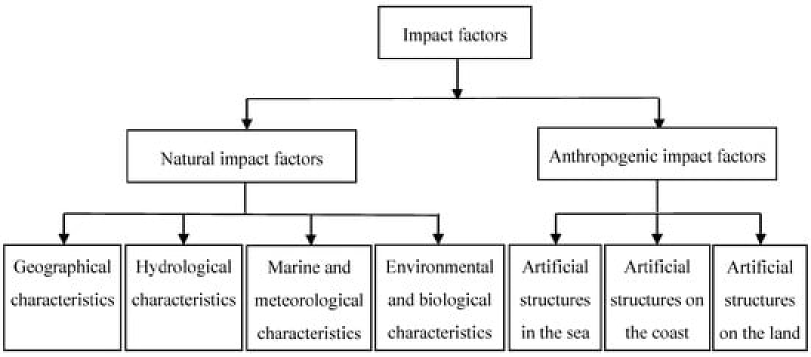

Figure 5. Impact factors of the coastal buffer zone [14].

- Natural impact factors:
  - Geographical characteristics: Beaches, reef coasts, wetlands, lagoons and tide pools, sand dunes, algae fields, submerged reefs, headlands, bays, estuary bars, islands, and coastline shape (straight or curved);
  - Hydrological characteristics: Groundwater level, river flow conditions, river channel shape, channel elevation, and estuary sediment transport;
  - Ocean and meteorological characteristics: Waves, tides, tidal currents, nearshore currents, typhoons, storm surges, and coastal sediment transport;
  - Biological characteristics: Aquatic species, intertidal species, and terrestrial species;
  - Environmental factors: Water quality, pollutants, nutrients, suitable habitat flow, and stratum subsidence.
- Anthropogenic impact factors (the coastline is used as the partition):
  - Artificial structures in the sea, such as artificial islands, artificial sneak reefs, and offshore embankments;

- Artificial structures on the coast, such as breakwaters, ports, reclaimed land, jetties, artificial headlands, groins, seawalls, revetments, diversion dikes, artificial beaches, and artificial wetlands;
- Artificial structures on the land, such as sand fences, sand fixers, windbreaks, disaster prevention drainage facilities, and other artificial structures (such as roads, houses, fishponds, and agricultural land) located in the coastal buffer zone.

Research on coastal buffer zones must consider the existing impact factors in coastal areas to understand their degree of effect on the prevention of natural disasters, coastal conservation, and ecology. We propose the division of the coastal area into coastal erosion, flooding, and storm surge subareas. The basis for this division must consider integrated studies on hydrodynamics, environment, and ecology. Furthermore, the research methods should include long-term field surveys, model experimental analyses, and numerical model simulations. In research applying numerical models, the following methods can be used to identify the impact factors of the coastal buffer zones (**Figure 6**):

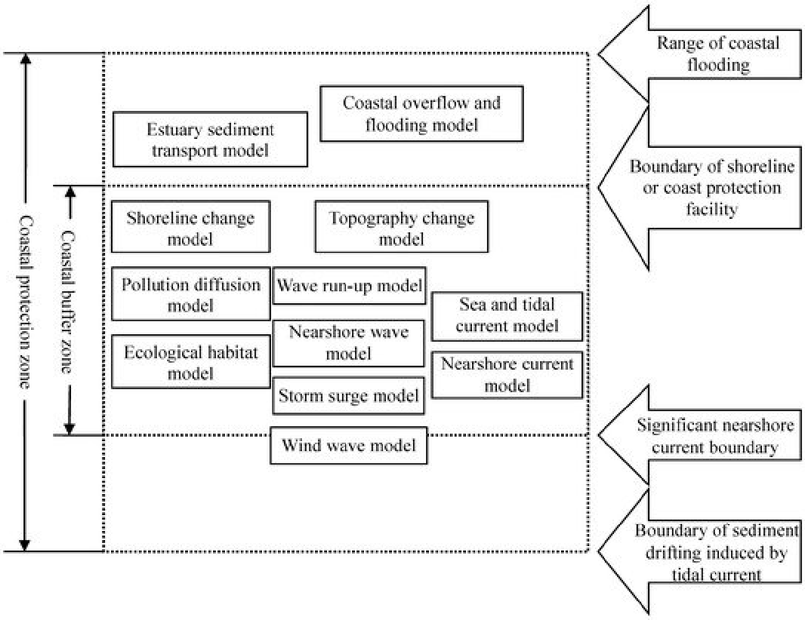

Figure 6. Schematic diagram of research on the application of numerical models to identify the impact factors of coastal buffer zones.

- Numerical models such as the wind wave models (e.g., WAM, SWAN, STWAVE, TOMAWAC, and WWM), nearshore wave field models (based on the mild-slope equation or Boussinesq-type equation, among others), wave run-up models (e.g., see Mase [15] and De Waal and van der Meer [16]), and others [17][18] can simulate and predict the wave conditions of the coastal buffer zone;
- Numerical models such as the tide models (e.g., see Zalesny et al. [19]), nearshore current models (e.g., see Svendsen et al. [20]), and estuary dynamic models (e.g., see Pao et al. [21]) can simulate and predict the flow conditions of the coastal buffer zone;
- Numerical models such as the sea level rise models (e.g., see Dayan et al. [22]), tidal level and storm surge models (e.g., see Dube et al. [23], Kim et al. [24], and Muis et al. [25]), coastal overflow and flooding models (e.g., see Gallien et al. [26] and Xie et al. [27]) can predict the potential rise in sea level and the possible range of flooding in the coastal buffer zone;
- Numerical model such as the shoreline and topography change models for sea areas (e.g., GENESIS and SPEACH [28][29][30]), headland theory models (e.g., see Hsu and Evans [31], Weesakul et al. [32], and Li et al. [33]), estuary sediment transport model (e.g., see Pao et al. [21]), and wind sand models (e.g., see Lo Giudice and Preziosi [34]) can predict the potential movement of sediment and dune sand in the coastal buffer zone as well as the changes in shoreline and topography of sea and land areas;
- Numerical model such as the pollution diffusion models (e.g., see James [35]), salinity or temperature distribution models (e.g., see Larson et al. [36] and Pu et al. [37]), and groundwater seepage models (e.g., see Park, et al. [10]) can predict water quality based on the concentration and distribution of nutrients and pollutants in the coastal buffer zone;

- Ecological habitat models (e.g., see Xu et al. [38]) and ecological engineering methods (e.g., Sulaiman and Mohidin [39]) can predict the distribution of suitable habitats for organisms in the coastal buffer zone and applicable ecological engineering.

Based on the hydrodynamics of and sediment transport by nearshore and tidal currents, Lan et al. [40][41] and Li [42] proposed a method for determining the boundaries of offshore and onshore areas in the coastal buffer zone (**Figure 7**). They used the SBEACH model combined with the wave run-up model (Flow3D®) to perform dynamic simulations of beach profile changes on different sections of the coast at the present state of sea level, and then set the boundaries of the offshore and onshore areas of the coastal buffer zone based on the typhoon waves during the 50-year return period, as shown in **Figure 8** and **Figure 9**. The offshore boundary is bounded by the farthest range of sediment drift simulated by the SBEACH model, and the onshore boundary is set at the maximum height of wave run-up. The preliminary delineation range was verified with the current coastal resources and coastal environmental impact factors, and a comprehensive analysis was conducted to establish the final range of the coastal buffer zone [43].

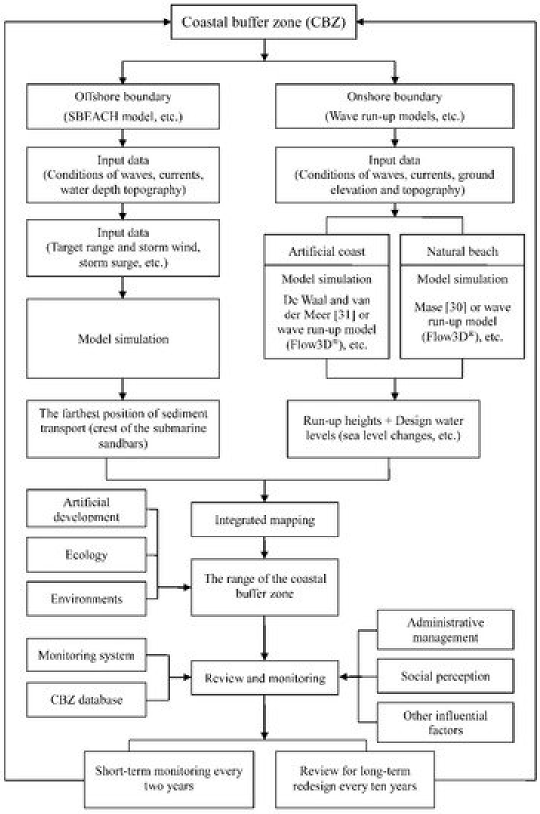

Figure 7. Recommended flow chart to design coastal buffer zones for coastal managers.

Figure 8. Preliminary planning results of coastal buffer zone using the SBEACH and wave run-up models (the estuary of Lanyang Creek, Yilan, Taiwan) [41]. (Red line: the onshore boundary of the coastal buffer zone; yellow line: the offshore boundary of the coastal buffer zone.).

Figure 9. Preliminary planning results of coastal buffer zone using the SBEACH and wave run-up models (Nanliao Fishing Port, Hsinchu, Taiwan) [41]. (Red line: the onshore boundary of the coastal buffer zone; yellow line: the offshore boundary of the coastal buffer zone.).

Focusing on the problems of special coastal areas, such as harbors, estuaries, coastal industrial areas, and small islands, Lan et al. [41] put forth the following suggestions regarding the appropriate layout of coastal buffer zones:

- For large harbors, because the breakwater extends to the open sea beyond the offshore boundary of the coastal buffer zone, there is no offshore boundary line for the region. Thus, the delineation of the onshore boundary also follows this principle;
- In estuarine areas, the onshore boundary of the coastal buffer zone should preferably connect with the riparian buffer zone;
- Small islands are surrounded by sea on all sides, and the intensity of typhoon waves varies in different seaward directions. Therefore, the buffer zone for each coastal segment simulated by the hydrodynamic models will also be

different. Thus, the offshore boundary of the coastal buffer zone of small islands should be set at the farthest water depth of sediment transportation as the unified boundary.

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