# Chapter 4. SEMI-ENCLOSED SEAS, ISLANDS AND AUSTRALIA PAN-REGIONAL OVERVIEW (S)

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**Contents**



## 1. Introduction

As a consequence of the flooding of the continental shelves by sea level rise at the end of the Last Glacial Period, the continents are surrounded today by shallow seas. Many of the inland seas, like the Baltic Sea, did not exist 10,000 years ago, or like the Black Sea have become filled with salty water while it was the largest fresh water body on Earth during the Pleistocene. The coastal seas are of prime interest to mankind since they contain a mosaic of complex and diverse ecosystems that involve rich natural resources and concentrated human activities, and provide a vital habitat for many commercial and endangered species. Their internal behavior affects their productivity, and they play an important role in the global carbon, nitrogen and phosphorus cycle because they receive massive inputs of these elements through anthropogenic sources and upwelling, exchange large amount of organic matter with the open oceans, and maintain productivity in higher trophic levels. In shallow water, nutrients are efficiently recycled many times, before becoming finally fixed in the sediments or being exported to the open ocean. There-

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fore, more productivity is maintained in the shallow and marginal seas than in most of the open ocean with positive effects on the harvest of fish and other marine species. A recent JGOFS synthesis indicated that the eutrophication-derived carbon deposit on the marginal seas partly compensate the missing anthropogenic $CO_2$ (Chen et al., 2004). As become highly eutrophic, the major problems today confronted with the marginal and shelf sea ecosystems are to assess types of possible structural changes possibly introduced by human-induced interventions in the next decades, to what extent they might be controlled, and implementation of possible strategies for sustainable use of their resources.

The semi-enclosed, marginal and shelf seas reviewed in this chapter as a part of the Pan-Regional overview of coastal oceans may be classified in terms of their morphological structures in three different groups: (i) nearly-enclosed basins with very limited exchanges with open oceans (e.g., the Baltic Sea, Mediterranean Sea, Black Sea, Red Sea, Arabian Gulf, Bohai Sea, Sea of Okhotsk, Japan/East Sea), (ii) partially-enclosed basins with moderate interactions with open oceans along their one or two boundaries (e.g., the North Sea, Yellow Sea, East China Sea, South China Sea), (iii) peripheral seas extending along continental margins and having strong interactions with open oceans along their two or three boundaries (e.g., the North Indian Ocean marginal seas, Outer Southeast Asia Sea, shelf seas around Australia and New Zealand). Aspects of the physical circulation, air-sea interactions and tides were overviewed by Church et al. (1998 – Vol. 11 The Sea). The overview presented in this chapter primarily focuses on their physical and ecosystem characteristics under four separate sections: (1) European semi-enclosed seas, (2) Arabian Peninsula and Northern Indian Ocean marginal seas, (3) East Asian (or Western North Pacific) marginal seas, (4) Australia-New Zealand shelf seas.

## 2. European semi-enclosed seas

### *2.1. Physical characteristics*

The European marginal seas considered here include four semi-enclosed basins encircling the continental Europe. The Baltic Sea and the North Sea cover the western periphery, whereas the Mediterranean and the Black Seas encircle its southern-southeastern periphery (Fig. 4.1). The Baltic and North Seas (described in Rodhe et al., Chapter 26) are connected with each other by the Skagerak-Kattegat-Belt Sea region system where the Danish Straits constitute the shallowest and narrowest sections of the Baltic Sea with the deepest sill depth of about 18 m. The average depth of the entire Baltic Sea is about 60 m, and typical basin depths vary in the range 100 to 250 m. The North Sea is largely a shelf sea with an average depth about 100 m. It is connected to the North Atlantic along its northern and the southwestern boundaries. The Norwegian Trench, with a maximum depth of 700 m extends along the Norwegian coast.

The Baltic Sea reveals a fjord-type two-layer circulation. The restricted water exchange through the Danish straits, its long renewal time (about 30 years), and comparatively large river discharges result in a very low mean salinity in the Baltic-Sea. The exchange of water through the Danish Straits, with low-saline outflows and high-saline inflows, is mainly forced by atmospheric events. The Baltic proper is strongly stratified by salinity. The surface salinity ranges from 8–9 in the south to 6–7 in the northern part of Baltic proper. A 50 to 70 m deep surface layer with no apparent vertical salinity gradient is separated from the weakly stratified deep water by a halocline. In addition, the surface layer becomes thermally stratified at a shallower depth in summer. The water in the deepest parts of the Baltic is renewed by infrequent, long-lasting extreme inflows through the Danish Straits. Except these periods of strong inflow the deep water is stagnant and eventually becomes anoxic. The frequency of these deep-water inflows has in fact decreased in recent decades, seemingly correlated with a pronounced positive North Atlantic Oscillation (NAO). Low salinity nature of the Baltic Sea results in the formation of sea ice every year. The entire Baltic Sea may be covered by ice during severe winters.

Figure 4.1 Location map and geographic setting of four semi-enclosed basins (The Baltic Sea, the North Sea, The Mediterranean Sea and The Black Sea) encircling the continental Europe.

In contrast, hydrographic conditions of the North Sea are characterized by a horizontal circulation system, stratified during the summer, with different dynamic regimes in its different regions. The North Sea is renewed rapidly on the order of one year. Most of the water enters from the northwestern boundary, circulates within the basin cyclonically, and flows out northward along the Norwegian Trench on the eastern side of the North Sea. Its average transport is around $2\,10^6$

$m^3 s^{-1}$. Relatively high salinity water also enters the North Sea through the British Channel, but at a far less transport rate. The salinity of the North Sea is close to 35. The central part of the North Sea is well-mixed vertically during winter and becomes stratified in summer due to heating. The tides are strong enough along the southern and western parts of the North Sea coasts to keep the water vertically mixed throughout the year, except near some river plumes. The Norwegian Trench region is stratified by salinity all year around due to the low salinity outflow, about 15 at the Kattegat, from the Baltic Sea and due to local river discharges. Kattegat is strongly stratified and its circulation is of estuarine type, i.e., entrainment of deep-water into the surface layer with an increasing surface-layer outflow along the Norwegian coast.

The Mediterranean Sea (Pinardi et al., Chapter 32) is separated from the Atlantic Ocean through the Strait of Gibraltar, and comprises the western and eastern basins, which are connected with each other through the Strait of Sicily. The eastern basin is further connected to the Aegean Sea with the several straits along the Cretan Sea and to the Black Sea through the Dardanelles and Bosphorus Straits. The basin depths are up to 4000–5000 m, but there are also extensive shelf areas. Pinardi et al. (Chapter 32) concentrates on six particular shelf regimes, three of which (the Gulf of Lions, the Northern Adriatic and the Egyptian shelves) are wide (>70 km) shelves and receive major river runoffs. Two other shelves along the Algerian and Israeli coasts are narrow (<30 km) shelves without significant runoff. The last one is the Sicily Strait that represents an extended shelf area without any relevant river input and is a large channel area for the exchange of water masses between the Eastern and Western Mediterranean sub-basins.

Difference in the many aspects of the physical characteristics between the northern and southern shelves is related to the Mediterranean precipitation regimes that result in zero runoff on the southern shores and river outflows on the northern shores. All the northern rivers have a spring maximum discharge connected to the ice-snow melting cycle and the precipitation maximum during winter. The noticeable exception is the Nile Delta, whose catchment basin extends further south to the tropical African wind belt and thus not regulated by the Mediterranean precipitation regime. Regulation by the Aswan Dam, however, has significantly reduced the Nile runoff.

The Mediterranean is a concentration basin, i.e. water losses exceed water gains from precipitation and runoff. In addition, the net heat budget of the basin is negative, so that the vertical thermohaline circulation is anti-estuarine, with waters exiting the Mediterranean at depths and entering from the Atlantic at the surface. The thermohaline circulation is of multi-decadal time scales with water mass formation in areas of the Northern Mediterranean. Both deep and intermediate waters form in the regions offshore the Gulf of Lions, the southern Adriatic and the northern Levantine basin, forced by intense heat losses during late winter (February-March) and influenced by the presence of a large scale cyclonic circulation driven by wind stress curl. The Aegean Sea has been a source of deep waters for the Ionian Sea abyssal plains during the eighties and first half of the nineties, but ceased to be so lately.

The sub-basin scale circulation has several time scales. The steady state component consists of permanent cyclonic and anticyclonic gyres that are wind-, and thermally-driven, superimposed to and interacting with the Gibraltar inflow sys-