Definition and Physical Characteristics of the World's Enclosed Coastal Seas

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Definitions of the geomorphic term "enclosed sea" are imprecise. Some available definitions are presented and reviewed. Based upon a quantitative morphometric ratio of {major axis length within the enclosed sea} to {entrance width}, fully "enclosed" seas are defined as having a ratio exceeding 4. If there is more than one entrance, the sea is defined as "semi-enclosed". Those seas with major axis length to the entrance width ratios less than 4 are defined as "enclosed bays", except if they have multiple entrances, in which case the term "semi-enclosed bay" is appropriate.

Data from the world's coastal enclosed seas, defined according to the new morphometric criterion, are presented. We identify 22 enclosed seas, 6 semi-enclosed seas, 9 enclosed bays and 5 semi-enclosed bays.

Additional Key Words: semi enclosed seas, enclosed bays, semi-enclosed bays.

Introduction

The definition, perception, and understanding of the terms "enclosed sea" and "semi-enclosed" sea are confused in the literature and do not have common acceptance. As has been already written for the term estuary, "they are rather like pornography, difficult to define, but you know it when you see it"! Accordingly we review the various definitions, and from a morphometric standpoint, propose a morphometrically precise definition for the terms "enclosed sea" and "semi-enclosed sea", and introduce the terms "enclosed" and "semi-enclosed bay".

The various examples of enclosed seas fitting the new definition on a world scale are then mapped, and data pertaining to them presented.

Definitions of Enclosed Sea and Semi-enclosed Sea

It is fair to assume that various disciplines define various morphological features with their own interest in mind. Thus the marine biologist will likely define an enclosed sea somewhat differently from an earth scientist, physical oceanographer or engineer, while an ecologist may not consider an enclosed sea a specific feature unless the ecosystem is different from adjacent oceanic waters (Ketchum, 1983).

A good example is the definition of enclosed and semi-enclosed seas according to the 1982 United Nations Convention on the Law of the Sea (Theutenberg, 1984), in which article 122 defines on politico-geomorphic criteria,

> "enclosed or semi-enclosed sea means a gulf, or basin or sea surrounded by two or more states and connected to another sea or the ocean by a narrow outlet...."

A clear definition of enclosed sea and semi-enclosed sea does not appear in the authoritative glossaries of oceanography (eg Baker, et al., 1966; Fairbridge, 1966; Gary,et al., 1972).

In the geological context, Gary, et al. (1972, p.652) define a "marginal" sea rather vaguely as:

> "a semi-enclosed sea adjacent to a continent and floored by a submerged continental mass."

In contrast, Baker, et al. (1966, p.101) define "adjacent, marginal, or shelf seas" as:

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> "a semi-enclosed sea adjacent to, or widely open to, and connected to the open ocean at the water surface, but bounded at depth by a submarine ridge. When shallow they are called shelf seas."

These definitions are related to those for "epeiric" seas (Baker, et al., 1966; p.58), being:

> "a shallow inland sea with restricted communication with the open ocean and having a depth less than 250m."

Somewhat different is the "inland sea" defined (Baker, et al., 1966; p.86) as:

> a sea surrounded by land which connects with an ocean or another sea by one or more narrow straits, examples being the Mediterranean and Baltic seas.

Nihoul (1982) also recognises that there is no clear definition of "semi-enclosed" sea, but notes that:

> "they are essentially bounded by land and there is limited communication with adjacent seas or oceans."

From the point of view of marine chemistry, Grasshoff (1975, p.456) states that:

> "The enclosed seas develop their own individual stratification, and the motions of their water masses frequently differ fundamentally from those of the neighbouring open sea"

Ketchum (1983, p.209) gives a definition of "enclosed" seas based on circulation, environment and ecology, such that the enclosed sea:

> "is connected with the open ocean in a way which modifies and controls the circulation within the sea and produces an environment and an ecosystem which is unique and different from the adjacent coastal waters"

Apart from the implication of being partially surrounded by land, there is considerable scope in the perceptions of enclosed and semi-enclosed seas. Clearly such features may be associated variously with political boundaries, submarine ridges, shallow bathymetry, salinity structure, geological criteria, and the uniqueness of ecosystems. Only those definitions by Nihoul (1982) and by Baker, et al.(1966) for an "inland sea" are based directly on topographic criteria.

An example of the confusion in applying the term enclosed sea is evident in the document entitled "An Outline of the World's Enclosed Coastal Seas" prepared for the EMECS'90 conference. Of the 11 examples presented, it is clear, as shown in the discussion below, that only 5 meet the criterion of "enclosed sea" *sensu stricto*, and 3 are quite inappropriate to be considered as either enclosed or semi-enclosed seas.

Towards a Precise Definition for "Enclosed" and "Semi-enclosed" Seas

Clearly encompassed within the term "enclosed sea" is the idea that the feature is restricted from the open oceanic conditions by land, and therefore, by implication, the physical oceanographic parameters, sedimentary regime,, and salinity circulation modifications produce an environment and ecosystem which is different from adjacent coastal waters.

However for a more precise definition we propose that as enclosed seas are morphological features unique in space, their definition should be based on morphometric criteria in the first instance. Moreover there should be a distinction between the concept of enclosed sea and an enclosed or semi-enclosed embayment. In this regard the work of Yanagi (1988) is notable in that he defined "enclosed bays" on the basis of the ratio of {maximum length of the major bay axis} to {entrance width}. For his restricted data on four Japanese enclosed bays, all exceeded a ratio of 5. We apply this concept to the enclosed/semi-enclosed seas, but to allow for a greater spread of data, we suggest a ratio of 4 is more appropriate, while still retaining restricted circulation within the enclosed sea.

The criterion of a ratio of length of the major axis within the enclosed sea to entrance width exceeding 4 is thus somewhat arbitrary, but such a value ensures that the enclosed sea is characterised by inhibited flushing capability, has different physical oceanographic characteristics of wave climate, salinity and temperature structure from the adjacent open ocean, is a marginal basin in the sedimentary sense, and is thus a likely pollutant trap, and that the enclosed sea will likely contain an ecosystem different from the adjacent open ocean or seas.

Accordingly we define the "enclosed sea" as:

> "a sea that is surrounded by land with a relatively narrow entrance, which is at least 4 times smaller in dimension than the longest axis within the enclosed basin."

Note that this definition has no requirement of a submarine ridge as a boundary for the enclosed sea, implicit in some of the definitions reviewed above. It is also quite general in regard to scale, so that smaller scale features would tend to merge with the concept of estuary. For practical purposes we restrict the term to features identifiable on a world map of scale 1 to 15-25 million.

The distinction that we draw between "enclosed" and "semi-enclosed" sea is that the semi-enclosed sea may have two or more entrances. The importance of multiple entrances is that the semi-enclosed sea may potentially be flushed from different directions depending on tides, storm surge, floods, or tsunami impacts, whereas the enclosed sea can only be flushed from the one direction.

Thus the Seto Inland Sea of Japan, the Aegean Sea, and the Gulf of Mexico are semi-enclosed seas, while Mediterranean Sea, Baltic Sea, Persian Gulf, and San Francisco Bay are enclosed seas, *sensu stricto*. Semi-enclosed seas should also follow the criterion of the entrance widths being at least 4 times smaller in magnitude than the longest axis within the enclosed basin.

A further distinction may be drawn for those examples which do not meet the criterion of entrance width being at least 4 times smaller in magnitude than the longest axis within the enclosed basin. For these cases we propose the term "enclosed" or "semi-enclosed bay" (Fig.1). Thus the Gulf of Thailand is an "enclosed bay", and the North Sea a "semi-enclosed bay". For such examples their more open characteristics mean that they are not so likely to possess physical oceanographic characteristics (wave climate, temperature and salinity structure), sedimentation characteristics, pollution trapping capability, and ecosystem uniqueness, specific to that embayment.

It is clearly possible to have examples of both enclosed and semi-enclosed seas within a larger system. For example the Kiel Bay of north Germany is a semi-enclosed bay, and the Gulf of Finland an enclosed sea, both situated within the larger enclosed Baltic Sea.

Examples of the World's Enclosed and Semi-enclosed Seas and Bays.

Based upon the new morphometric definition presented above, the Readers Digest World Atlas (1965) was perused and data extracted for the major examples of enclosed and semi-enclosed seas and bays. The examples, classified according to our new morphometric definition, are presented in Fig. 2. Table 1 presents both morphometric temperature, salinity, tidal range, maximum current data for these examples, from which 22 enclosed seas, 6 semi-enclosed seas, and 9 enclosed and 5 semi-enclosed bays are identified.

Summary

1). The authoritative references do not project clear consensus definitions of the terms "enclosed" and "semi-enclosed" seas.

2) Accordingly we propose a precise definition based on morphometric configuration whereby enclosed seas are defined as being surrounded by land with a relatively narrow entrance, which is at least 4 times smaller in dimension than the longest axis within the enclosed basin.

3) From analysis of world examples we identify 22 enclosed seas, 5 semi-enclosed seas, 9 enclosed bays and 5 semi-enclosed bays.

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Figure 1: Morphometric Definitions of Enclosed/Semi-enclosed Seas and Bays

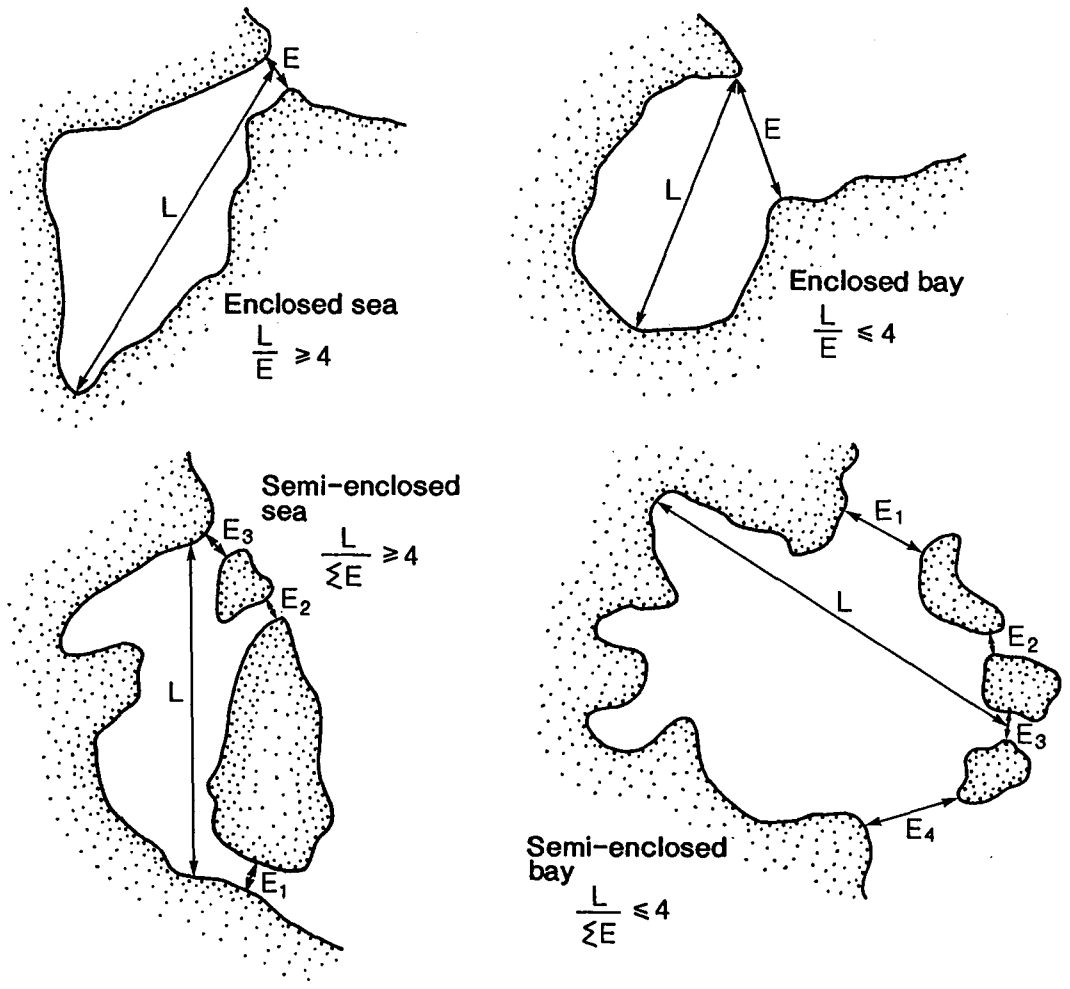

Table 1: Classification and Physical Characteristics of Enclosed and Semi-enclosed Coastal Seas and Bays.

LOCATION	NUMBER OF ENTRANCES	ENTRANCE WIDTH E (KM)	MAJOR AXIS LENGTH L(KM)	RATIO (MAX L:E)	AREA (KM SQ.)	ENTRANCE DEPTH (M)	MEAN DEPTH (M)	MEAN SAL. (PPT)	WINTER TEMP. (C)	SUMMER TEMP. (C)	TIDAL RANGE (M)	MAX. TIDAL SPEED (M/S)
ENCLOSED SEAS												
1.BLACK SEA	1	3	1149	383.0	461000	40	1166	17.0	0.0	22.0	0.09	-
2.MEDITERRANEAN SEA	1	21	3600	171.0	2516000	320	1494	38.7	8.0	25.0	0.30	2.45
3.BALTIC SEA	1	116	1496	13.0	386000	18	55	11.5	0.0	18.0	0.15	-
4.RED SEA	1	25	2253	90.0	450000	110	558	39.3	23.0	28.0	0.90	0.50
5. PERSIAN GULF	1	49	990	20.0	241000	25	40	39.0	15.5	32.0	3.70	2.10
6.GULF OF ST.LAWRENCE	1	160	1100	7.0	238000	200	127	30.5	-1.8	8.0	3.80	2.00
7.HUDSON BAY	1	230	1592	7.0	1232000	155	128	30.0	0.0	9.0	-	0.90
8.GULF OF CALIFORNIA	1	208	1100	5.0	177000	3000	818	34.7	20.0	28.0	2.00	3.00
9.ADRIATIC SEA	1	75	790	10.0	107970	500	100	38.6	-	24.0	-	-
10.GULF OF FINLAND	1	45	320	6.0	34145	100	37	4.0	-	-	0.15	-
11.GULF OF BOTHNIA	1	120	690	6.0	135918	<50	67	7.0	-	-	0.03	-
12.GULF OF RIGA	1	48	190	4.0	8963	<50	23	-	-	-	-	-
13.TOKYO BAY	1	10	50	5.0	1173	-	-	-	-	-	-	-
14.MUTSU BAY	1	10	60	6.0	1840	-	-	-	-	-	-	-
15.KAGOSHIMA BAY	1	10	80	8.0	1224	-	-	-	-	-	-	-
16.ARIAKE SEA	1	20	120	6.0	2400	-	-	-	-	-	-	-
17.SAN FRANCISCO BAY	1	5	95	19.0	1163	-	-	-	-	-	-	-
18.WHITE SEA	1	125	600	4.0	95000	50	150	25.0	0.0	20.0	7.00	1.80
19.BAY OF FUNDY	1	67	245	4.0	16400	30	30	32.0	-	-	12.00	1.50
20.LONG ISLAND SOUND	1	22	184	7.0	5000	80	20	-	-	-	1.10	2.20
21.DELAWARE BAY	1	15	77	5.0	1200	40	10	-	-	-	1.50	1.00
22.CHESAPEAKE BAY	1	18	337	19.0	15500	14	20	20.0	-	-	0.91	1.00
SEMI-ENCLOSED SEAS												
23.SEA OF JAPAN	4	196	2400	12.0	978000	150	1350	34.0	4.0	22.0	0.50	1.80
24.SETO SEA	2	60	400	7.0	8274	30	100	19.0	-	24.0	-	-
25.GULF OF MEXICO	2	420	1600	17.0	1543000	800	1512	-	-	-	-	-
26.OSAKA BAY	2	10	60	6.0	1836	-	-	-	-	-	-	-
27.SEA OF OKHOTSK	NUMEROUS	650	2580	4.0	1590000	1920	859	33.5	-1.8	18.0	13.00	-
28.IRISH SEA	2	116	370	4.0	103000	40	130	34.4	5.0	16.0	6.00	1.00
ENCLOSED BAYS												
29.NORTH SEA	1	400	1060	2.6	575000		94	34.8	8.0	15.0	7.00	2.60
30.SPENCER GULF	1	80	200	2.5	33000	50	20	40.0	10.0	29.0	3.90	1.00
31.GULF OF THAILAND	1	420	980	2.0	503000	58	46	30.5		26.0	0.80	0.52
32.RIO DE LA PLATA	1	200	300	1.6	642000	-	-	-	-	-	-	-
33.FIRTH OF THAMES	1	16	62	3.0	1240	30	10	34.0	-	18.0	3.80	2.00
34.BAFFIN BAY	1	500	1697	3.3	140000	600	500	34.5	-0.4	0.4	-	0.40
35.YELLOW SEA	1	478	857	2.0	417000	80	60	30.5	2.8	28.0	4.5-8.8	1.00
36.VAN DIEMEN GULF	1	70	170	2.4	11900	-	-	-	-	-	-	-
37.GULF OF ST.VINCENT	1	100	320	3.0	9800	50	30	-	-	-	0.40	
SEMI-ENCLOSED BAYS												
38.SULU SEA	NUMEROUS	470	950	2.0	250000	400	1139	35.0	27.0	28.0	-	3.40
39.KIEL BAY	2	120	40	3.0	4000	-	-	-	-	-	-	-
40.SHARK BAY	2	75	250	3.0	25000	-	-	-	-	-	-	-
41.CELEBES SEA	NUMEROUS	745	1400	2.0	472000	1400	4000	34.6	27.0	28.0	2.2	0.67
42.AEGEAN SEA	5	200	690	3.5	53920	200	500	39.0	-	23.0	-	-

Fig. 2: World Distribution of Enclosed and Semi-enclosed Seas and Bays.