WATER TYPES IN THE NORTH SEA AND THEIR CHARACTERISTICS

by

T. LAEVASTU

Meteorology & Oceanography Division
Hawaii Institute of Geophysics
University of Hawaii

HAWAII INSTITUTE OF GEOPHYSICS NO. 24

August, 1962

WATER TYPES IN THE NORTH SEA

AND THEIR CHARACTERISTICS

by

T. LAEVASTU

Meteorology & Oceanography Division
Hawaii Institute of Geophysics
University of Hawaii

HAWAII INSTITUTE OF GEOPHYSICS REPORT NO. 24

August 1962

WATER TYPES IN THE NORTH SEA

AND THEIR CHARACTERISTICS

by

T. Laevastu

Introduction

In various fisheries and oceanographic problems, it is necessary to classify the surface water types and to determine their distribution and their changes with the seasons. When the surface water types are defined on the basis of long-term average conditions, it becomes possible to detect easily any year to year changes which especially affect fisheries. In contrast to deep-water masses, the surface water types are modified by interaction between the sea and air, and between the coast and the bottom. Furthermore, intensive mixing between different water types and between surface and deep water occurs in many places. In determining the characteristics of given water types, these interactions and processes must be considered. In the following paper an attempt is made to characterize the water types in the North Sea.

Characterization of water types

For practical purposes, the water types should be characterized by the properties of the surface layer (ca. 1 m) which are easily observable while underway. There are no truly conservative properties at the surface. Therefore, besides the conventional water mass characterization properties of temperature and salinity, several other properties must be used. Most useful of these additional properties are: a) turbidity, which indicates several conditions (presence of high quantitities of plankton; inorganic suspended matter, swirled up from the bottom or transported with fresh water); b) biological properties (specific zooplankton and/or phytoplankton communities and/or indicator species); and c) depth of water and/or type of coast.

The range and peculiarities of seasonal changes of the properties used for characterization should also be specified together with seasonally varying horizontal and vertical mixing conditions.

Water types in the North Sea

The characteristics of eight water types in the North Sea are given in Table 1. In this table, synonyms of earlier classifications made on different bases, are also given (Kalle - on the basis of hydrographical and chemical properties; Russell- zooplankton communities and indicator species; Graham - plankton types; and Braarud, Gaarder and Grøntved - spring phytoplankton communities). At this stage of this study no exact numerical values (mean values or seasonal ranges) are given to the physical properties. Plankton communities are not indicated also, as these are not yet well established. References to the biological classifications are given in the last column.

Average summer and winter boundaries of the water types are shown in Figure 1. The boundaries must be considered as relatively wide transition zones, variable to some extent from season to season and from year to year. The variations are also affected by the variations in inflow. Some available data on inflow (after Kalle) are given in Figure 2.

The boundaries refer to surface conditions which might differ considerably in some regions, or which might be determined by the flow on the bottom, mixing and stratification. Two cross sections (Figures 3 and 4) illustrate the average surface conditions during August when the differences are greatest. Stratification and its seasonal changes are described in Figure 5 (after Dietrich).

Seasonal changes

The seasonal changes are composed of variations of local surface properties, caused by local sea-air exchange processes, mixing, and advection, and variations of water type extent (boundaries), caused by variations in inflow and prevailing winds. Temperature is the most easily measured surface property and also the most indicative of seasonal changes. For this reason, the variation of temperature in one type location (shown in Figure 2) for each water type is shown in Figures 6 to 13. The heavy middle line indicates the monthly average surface temperature variation in the given type location, (taken from Lowestoft - ICES charts) and the bordering lines indicate the monthly average maximum and minimum surface temperatures in the water type. Several singularities of these curves indicate various processes, characteristic

For given water types. The time of turnover in the fall, if present, is indicated by a "kick" in the average temperature; most intensive warming in the spring is indicated by the narrowness between maximum and minimum values; and the temperature of bottom water is usually indicated at the point where the monthly average temperature line is tangent to the minimum temperature line.

Synoptic oceanography (hydropsis) is a near future goal in the North Sea. For this service, water type characterization is needed and it is hoped that the present outline, with some modification, will serve the purpose.

REFERENCES

Braarud, T., K. Ringdal-Gaarder and J. Grötved, 1953: The phytoplankton of the North Sea and adjacent waters in May 1948. Rap. Cons. int. Explor. Mer. 133, 87 pp.

Fisheries Laboratory, Lowestoft and ICES Service Hydrographique, Charlottenlund: Monthly mean surface temperature and salinity charts for the North Sea.

Graham, M. (ed.), 1956: Sea fisheries: their investigation in the United Kingdom, E. Arnold, London. 466 pp.

Kalle, K., 1949: Die natürlichen Eigenschaften der Gewässer. Handbuch der Seefischerei Nordeuropas, Schweizerbart, Stuttgart, 1(2): 1-37.

_____ , 1953: Der Einfluss des englischen Küstenwassers auf den Chemismus der Wasserkörper in der südlichen Nordsee. Ber. Dtsch. Wiss. Komm. Meeresforsch. 13(2): 130-35.

Russell, F. S., 1939: Conditions in North Sea as indicated by plankton. J. Cons. int. Explor. Mer. 14: 171-92.

TABLE 1

NORTH SEA

WATER MASSES, THEIR CHARACTERISTIC AND DISTRIBUTION

NO.	NAME	CHARACTERISTICS	DISTRIBUTION	SYNONYMS
1	North Atlantic Water	High salinity (>35‰); poor in nutrients; low turbidity; relatively warm in winter, cool in summer, seasonal temperature change relatively small, ca. 6°C; homohaline, but thermally stratified; no direct coastal influence; depth ca. 100 m.	Entering partly between Orkney and Shetland, but mainly north from Shetland, flowing to south and mixing in the gyral on the northeast slope of Dogger Bank. The width is considerably greater during the winter.	Kalle - N. Atlantic Water; Russell - N. Atlantic Water; Graham - Mixed oceanic and coastal water; Braarud et al.- northern 1/3 -Central Atlantic Community, southern 2/3 - Atlantic Southward Extension Community
2	Channel Water	High salinity (>35‰); poor in nutrients; low turbidity; relatively warm, especially in winter; seasonal temperature change ca. 10°C; homohaline and homotherm; moderate coastal influence; shallow area.	Entering through Dover-Calais Strait, distribution in narrow strip to northeast, reaching the gyral in the northeast part of Dogger Bank.	K. - Channel Water; R. - Channel Water; B. - Southern Bight Community
3	Skagerrak Water	Low salinity (<34‰); poor in nutrients; medium to low turbidity; low temperature, seasonal temperature change ca. 13.5°C; pronounced seasonal change in salinity; stratified during entire year; moderate coastal influence; deep area.	A mixture of Baltic Water flowing out along the Norwegian coast. At about 59°N, a tongue of this water often reaches the central part of the North Sea (Water type 7) and some mixing also takes place between 57-58° (Water type 8)	K. - Skagerrak Water; R. - Skagerrak Water; G. - Sagitta setosa Water B. - South Norwegian Coastal Community

TABLE 1 (continued)

NO.	NAME	CHARACTERISTICS	DESCRIPTION	SYNONYMS
4	Scottish Coastal Water	Medium salinity (34-35°/o); medium in nutrients; medium to high turbidity; seasonal temperature change ca. 7°C; homohaline and homotherm; strong coastal influence and intensive mixing, relatively shallow area.	Atlantic water, flowing towards south along the coast and forming gyrals in the bays. Receives fresh water from several rivers and is mixed by strong tidal currents. In width, the distribution along the coast is relatively narrow.	K. - (none); R. - Mixed Scottish Coastal Water; G. - Mixed Oceanic and Coastal Water(same as 1) B. - northern half - Orkney-Shetland Community, southern half - Western Coastal Community;
5	English Coastal Water	Low salinity (34-34.5°/o); rich in nutrients; high turbidity; low temperature, seasonal change 11°C; homohaline and homothermal; pronounced coastal influence; shallow area.	Keel-shaped enclosure between Channel Water and North Atlantic Water; flow in general to northeast reaching the center of a gyral south of Dogger Bank.	K. - English Coastal Water R. - English Coastal Water G. - Mixed Oceanic and Coastal Water and Sagitta setosa Water B. - East Anglia Coastal Community.
6	Continental Coastal Water	Low salinity (≤34 %); rich in nutrients; high turbidity, relatively cool in winter, warm in summer, seasonal temperature change ca. 13.5°C; some haline stratification off estuaries, but usually mixed; pronounced coastal influence; shallow area.	Narrow strip off the continental coast, (wider in German Bight). Mixed in the gyral in the German Bight and flowing north into Skagerrak-Katteget along the Danish Coast.	K. - Continental Coastal Water R. - Continental Coastal Water (subdivided into Flemish Coastal and German Bight Water); G. - Coastal Water; B. - German Bight Community

TABLE 1 (continued)

NO.	NAME	CHARACTERISTICS	DESCRIPTION	SYNONYMS
7	Northern North Sea Water	High to medium salinity; medium to low in nutrients; low turbidity; seasonal temperature change ca. 10°C; haline stratification present; little influenced by coast; relatively deep area.	Basically North Atlantic Water (type 1) which is modified by local exchanges in the North Sea. Includes some mixtures of water type 3 and 4; net flow variable and entirely wind-dependent (usually towards southeast). Distribution narrow in winter.	K. - (none) R. - North Central (a sub-div. of Central North Sea Water); G. - Mixed Oceanic and Coastal; B. - Viking Bank and Cut Community.
8	Central North Sea Water	Medium salinity (34-35 °/o); medium in nutrients; medium turbidity; seasonal temperature change ca. 10.5 C; homohaline, but thermally statified; no direct coastal influence; medium depth (relatively shallow on Dogger Bank).	Covering the central North Sea, especially over Dogger Bank and northeast of it. A mixture of five other types.	K. - Central North Sea Water; R. - South Central (a sub-division of Central North Sea Water) G. - Dogger Bank Swirl and Sagitta setosa Water B. - Dogger Bank Community.

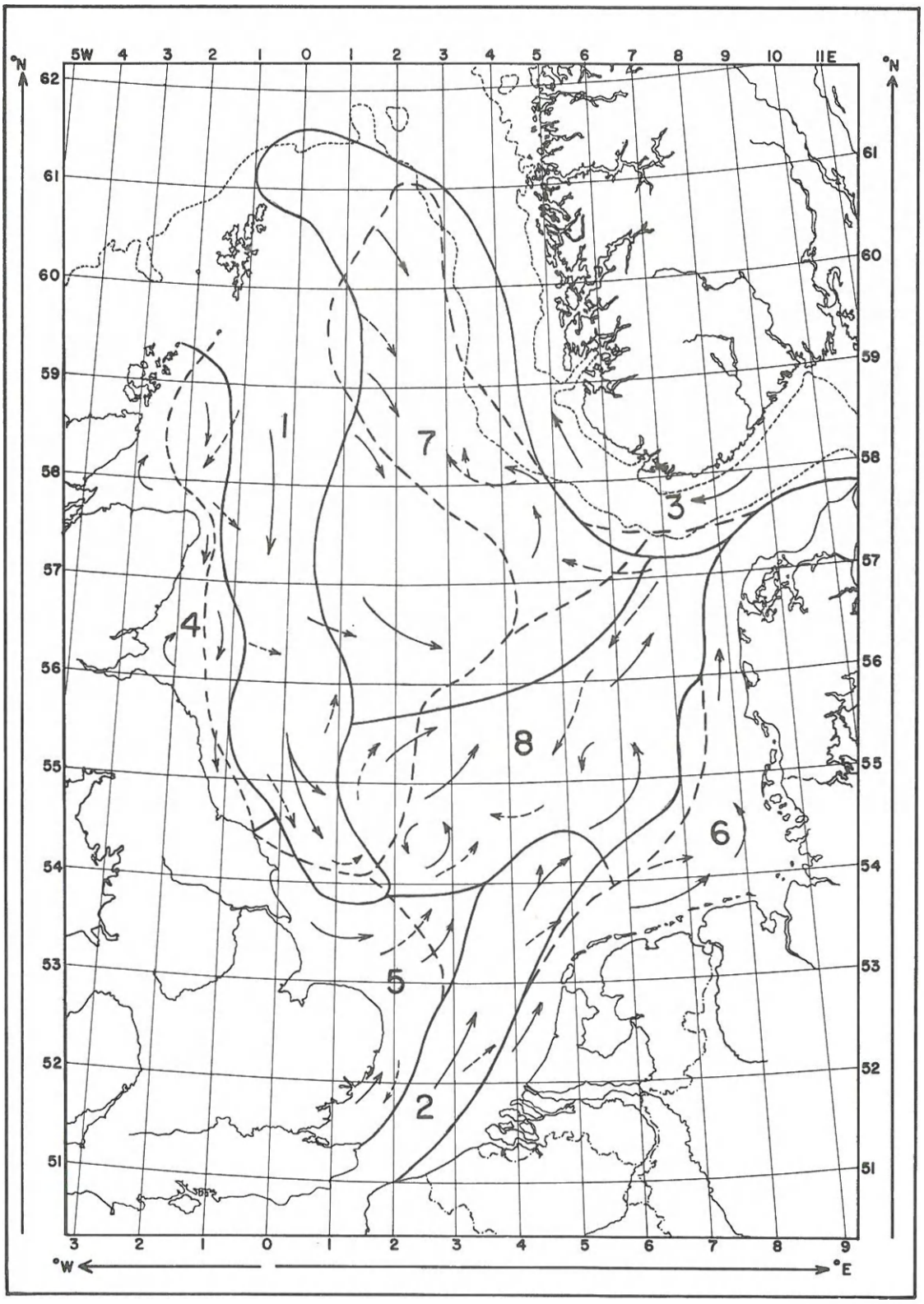

Figure I. Summer and winter boundaries of water types and net currents at the surface and at the bottom. (For names of the water types see corresponding numbers under Figure 2.)

——→ Surface net current, summer

- - - -→ Bottom net current, summer

—— Summer boundaries

- - - - Winter boundaries

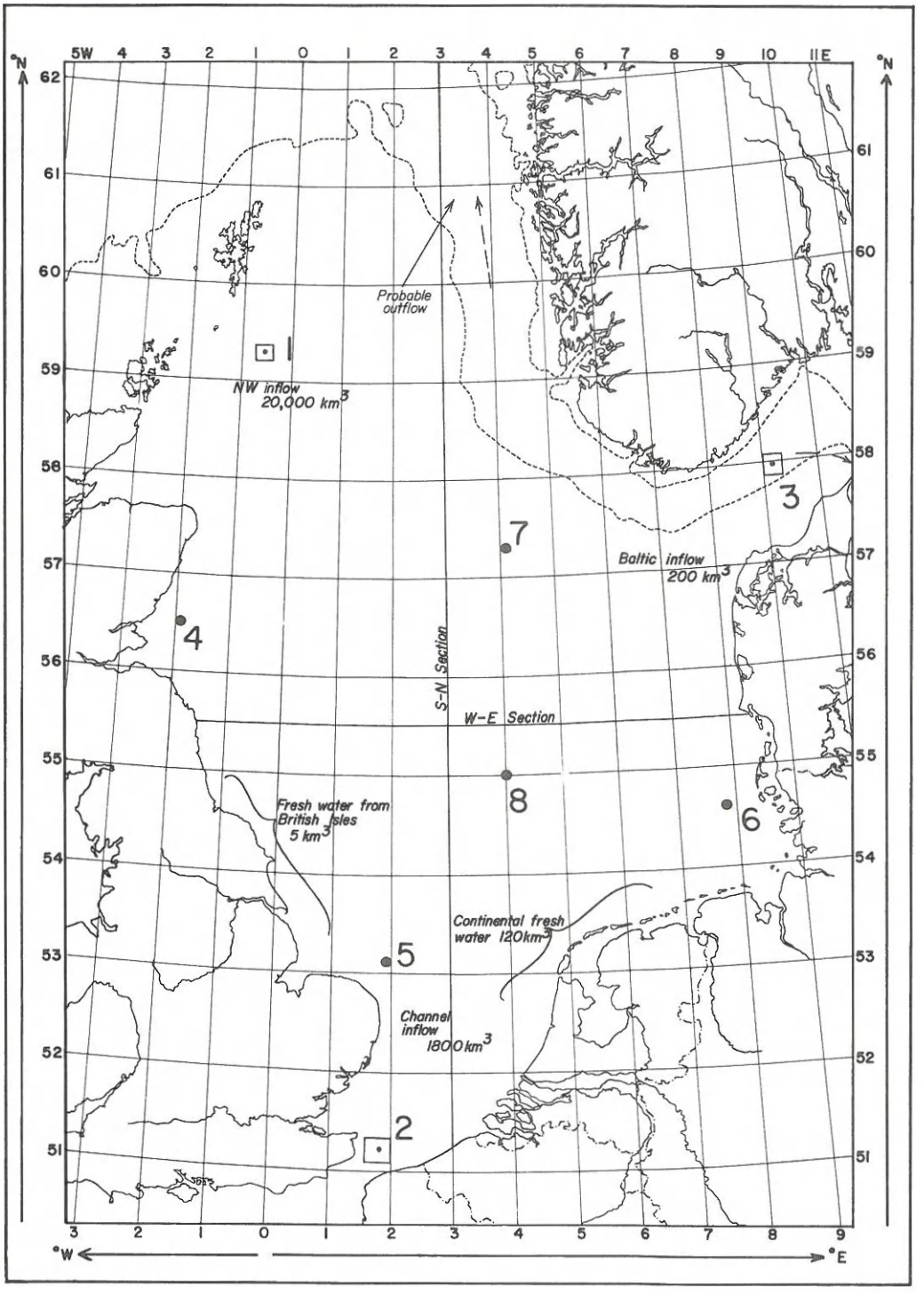

Figure 2. Locations of N-S and E-W sections; localities of water types; and inflow of fresh and salt water in km^3 per year (estimated from the data given by Kalle 1949).

⊡ Primary or original water types

• Secondary or mixed water types

Water Type

No.	Name
1	North Atlantic Water
2	Channel Water
3	Skagerrak Water
4	Scottish Coastal Water
5	English Coastal Water
6	Continental Coastal Water
7	Northern North Sea Water
8	Central North Sea Water

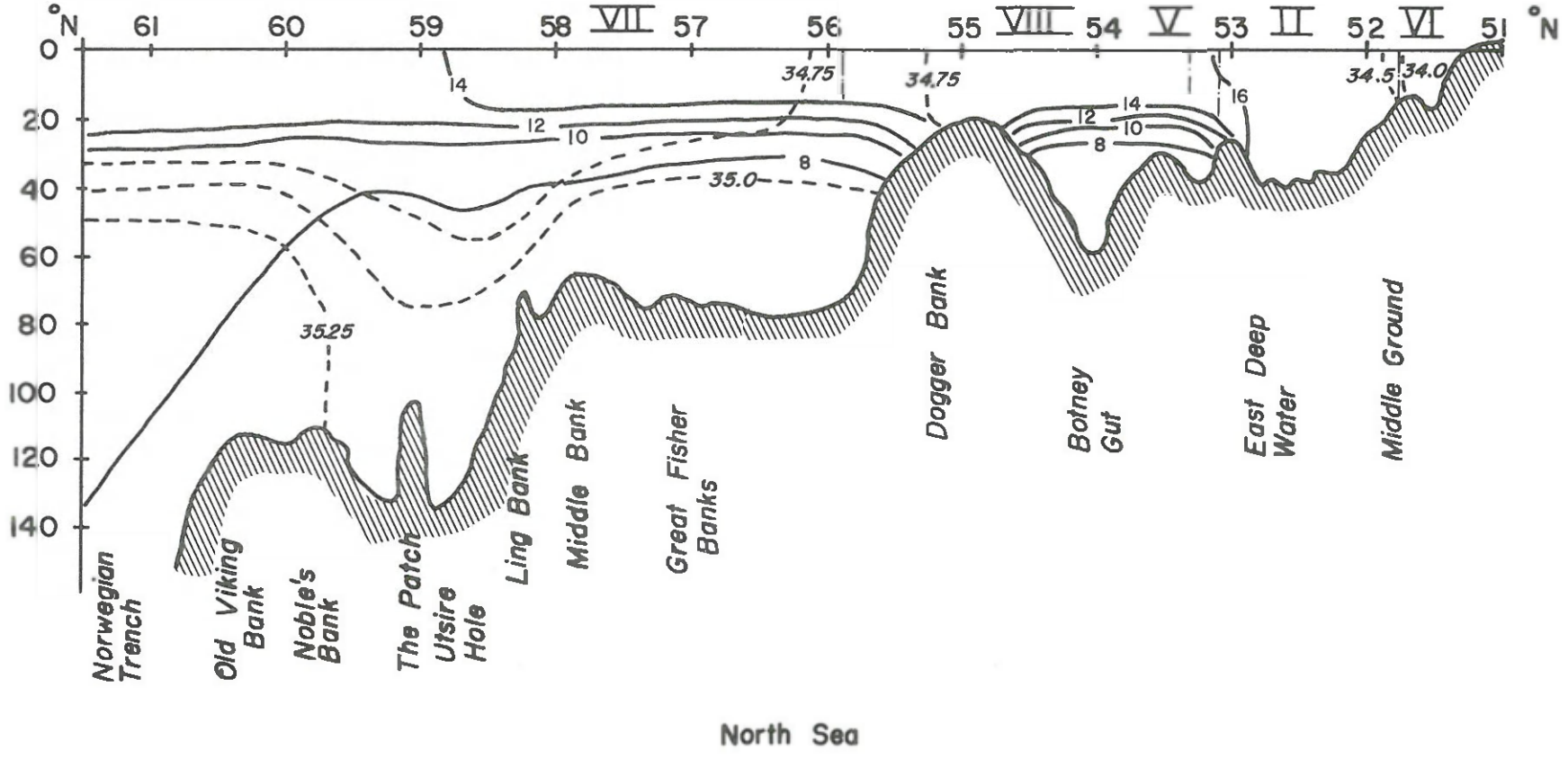

FIGURE 3. N-S SECTION ALONG 3°E. AVERAGE DISTRIBUTION OF TEMPERATURE (°C) AND SALINITY (°/oo) IN AUGUST. APPROXIMATE BOUNDARIES AND NUMBERS OF WATER TYPES ARE INDICATED. (THE WATER TYPE NUMBERS CORRESPOND TO THOSE ON FIGURE 2 AND TABLE 1.)

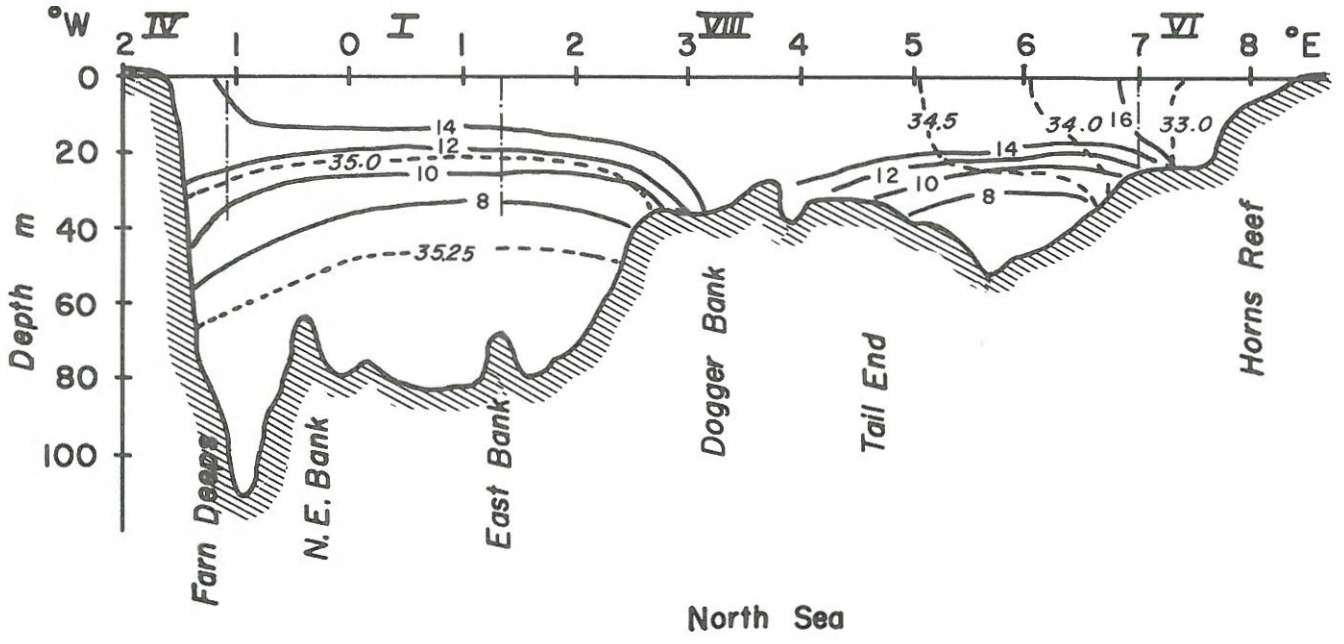

FIGURE 4. W-E SECTION ALONG 55°30'N (INTERNATIONAL R SECTION). AVERAGE DISTRIBUTION OF TEMPERATURE (°C) AND SALINITY (°/00) IN AUGUST. APPROXIMATE BOUNDARIES AND NUMBERS OF WATER TYPES ARE INDICATED. (THE WATER TYPE NUMBERS CORRESPOND TO THOSE ON FIGURE 2 AND TABLE 1)

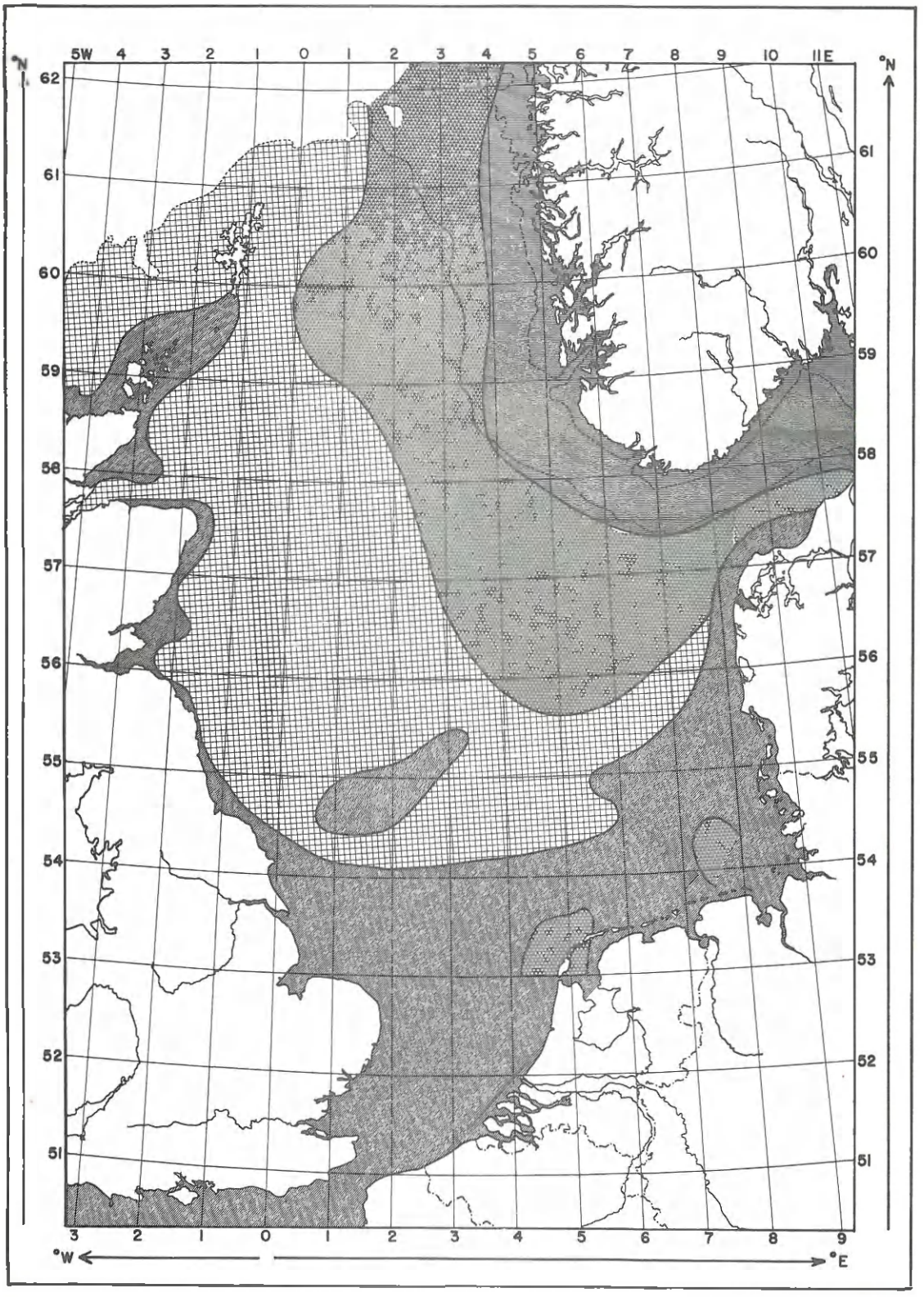

Figure 5. Hydrographical regions of the North Sea. (after Dietrich)

- Whole year homohaline; seasonally or whole year thermally stratified.
- Whole year homohaline and homotherm.
- Seasonally or whole year haline stratification present; annual salinity changes small in surface layers, regular in bottom layers.
- Seasonally or whole year haline stratification present; annual salinity change pronounced, regular in bottom layers.

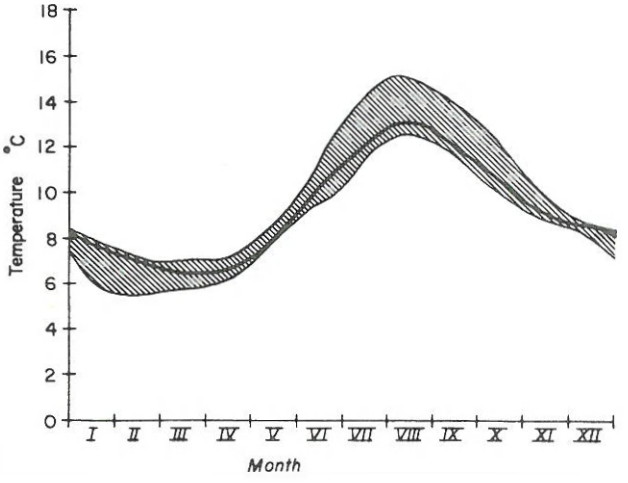

FIGURE 6. ANNUAL VARIATION OF MONTHLY AVERAGE SEA SURFACE TEMPERATURE IN NORTH ATLANTIC WATER (WATER TYPE 1). THE POSITION OF THE TYPE LOCATION IS GIVEN ON FIGURE 2. HEAVY CURVE GIVES THE MONTHLY AVERAGE SURFACE TEMPERATURE IN THE INDICATED TYPE LOCATION AND THE UPPER AND LOWER CURVES GIVE THE MAXIMUM AND MINIMUM MONTHLY AVERAG TEMPERATURE IN THE WATER TYPE AREA (GIVEN ON FIGURE 1).

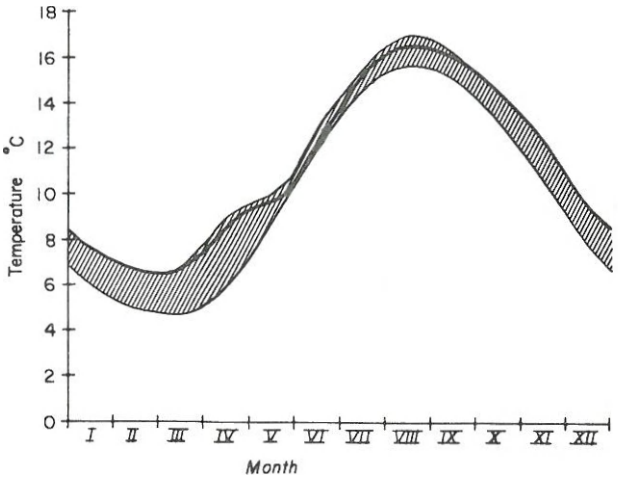

FIGURE 7. ANNUAL VARIATION OF MONTHLY AVERAGE SEA SURFACE TEMPERATURE IN CHANNEL WATER (WATER TYPE 2). EXPLANATION, SEE FIGURE 6).

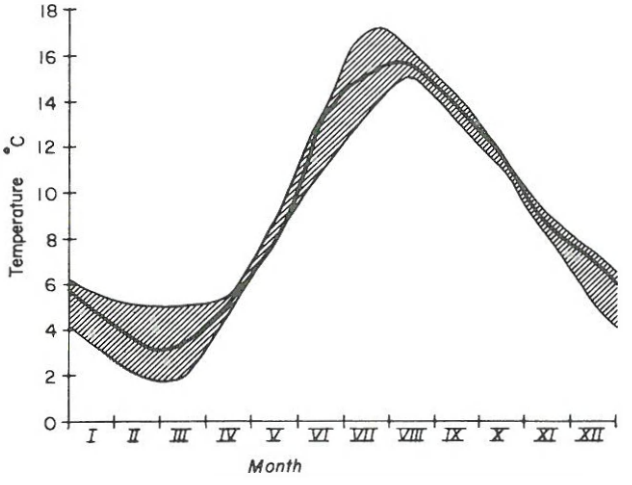

FIGURE 8. ANNUAL VARIATION OF MONTHLY AVERAGE SEA SURFACE TEMPERATURE IN SKAGERRAK WATER (WATER TYPE 3). EXPLANATIONS, SEE FIGURE 6.

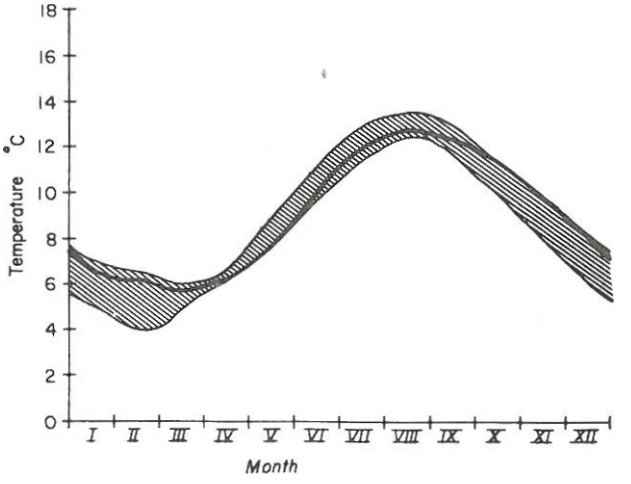

FIGURE 9. ANNUAL VARIATION OF MONTHLY AVERAGE SEA SURFACE TEMPERATURE IN SCOTTISH COASTAL WATER (WATER TYPE 4). EXPLANATION, SEE FIGURE 6.

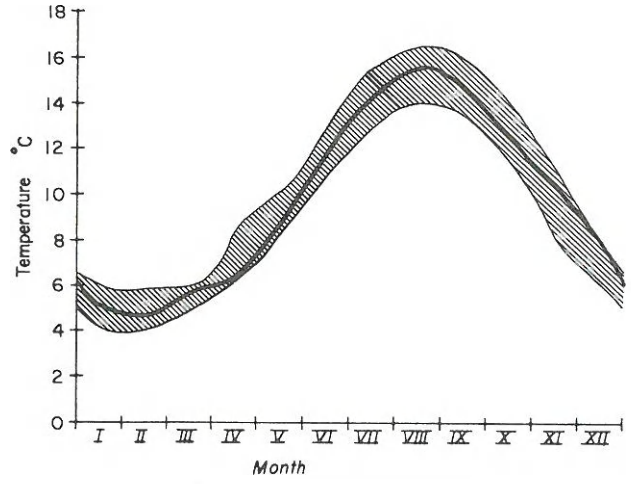

FIGURE 10. ANNUAL VARIATION OF MONTHLY AVERAGE SEA SURFACE TEMPERATURE IN ENGLISH COASTAL WATER (WATER TYPE 5). EXPLANATION, SEE FIGURE 6.

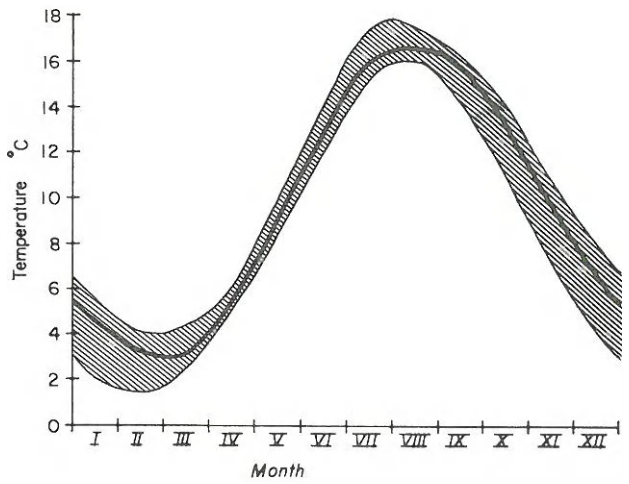

FIGURE 11. ANNUAL VARIATION OF MONTHLY AVERAGE SEA SURFACE TEMPERATURE IN CONTINENTAL COASTAL WATER (WATER TYPE 6). EXPLANATION, SEE FIGURE 6.

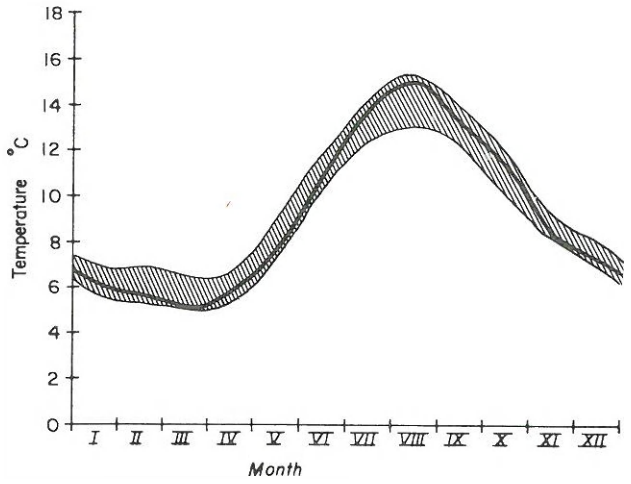

FIGURE 12. ANNUAL VARIATION OF MONTHLY AVERAGE SEA SURFACE TEMPERATURE IN NORTHERN NORTH SEA WATER (WATER TYPE 7). EXPLANATION, SEE FIGURE 6.

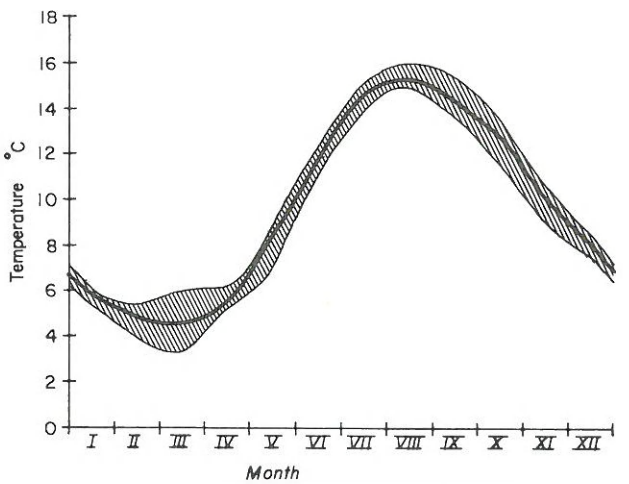

FIGURE 13. ANNUAL VARIATION OF MONTHLY AVERAGE SEA SURFACE TEMPERATURE IN CENTRAL NORTH SEA WATER (WATER TYPE 8). EXPLANATION, SEE FIGURE 6.