

# **Fisheries Hydrography**

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Fisheries hydrography relies upon the basic sciences – physics, chemistry and pure biology – as well as composite sciences such as ecology and marine geology. Fisheries hydrography is the study and application of oceanography, maritime meteorology and aquatic ecology to those practical problems in fisheries which are related to the productivity of the oceans or to the fishery resources, to the behaviour (aggregation, dispersion, migration, etc.) of various specimens belonging to the marine biomass, to the availability of fish and other fishable marine animals to the fisheries, and to the effects of oceanographic and meteorological conditions on the conduct of fishery. It is not possible to separate fisheries hydrography distinctly from the rest of oceanography, since its aim is to obtain such oceanographic information in such a manner that it can be applied to a variety of fisheries problems. i.e., to understand the behaviour of fish in various environmental conditions and their distribution and abundance in relation to environment and to apply this knowledge for improving the income of fishermen and fishing industries as well as for improvement of working conditions of fishermen. It covers both the basic scientific and applied aspects of research and the technology of developing research as well.

The fluctuations in the environmental conditions have a profound influence on the aperiodic and seasonal migrations and occurrence of fish. Furthermore, the conditions in the aquatic environment and their changes influence the recruitment, survival and growth of the fish. The environment also interferes with biological activities as spawning and growth.

Knowledge of behavior of fish in relation to the environmental conditions, which are easy to be observed by fishermen, is of practical importance for fisheries. This knowledge of the reactions of fish to various environmental stimuli is most useful for the location of fishable concentrations of fish and enables certain improvements to be made in fishing gear and fishing methods.

## **Temperature**

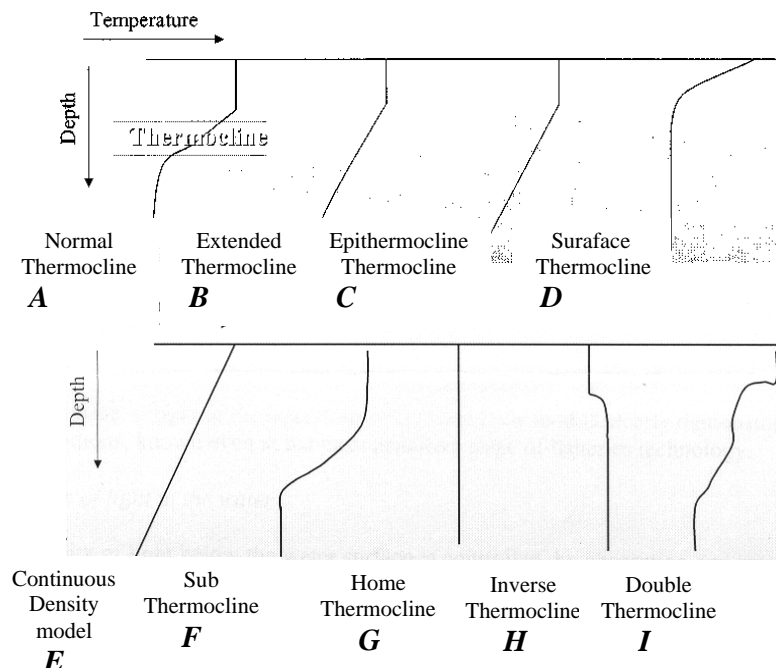
Temperature is the most easily determined environmental factor. Therefore numerous workers have attempted to correlate the behaviour of fish with seawater temperature and its fluctuations. Such changes in oceanic environment are, of course, very often only concomitant changes of other factors, such as currents, whose direct influence maybe considerable, while the actual influence of temperature may be of limited significance only. Nevertheless, in most cases the temperature may serve as a most useful indicator of the prevailing and changing ecological conditions. Not only the actual temperature, with its range of fluctuations, but its horizontal and vertical gradients, varying from place to place, must be taken into account when using the temperature as direct or indirect ecological indicator.

The surface waters of the oceans are usually isolated from the colder deep waters by a relatively sharp change of temperature, called '*thermocline*' or '*temperature discontinuity layer*', which can be either a 'permanent thermocline' or 'seasonal thermocline'. These thermoclines appear between the depths of 10 and 200 m. The surface waters above the thermocline are usually close to homothermal. However, local and seasonal variations occur depending on the factors, which determine the temperature of the surface and the mixing.

Some typical temperature structures are shown in Fig. 1. There are three basic types of temperature structure; A, normal thermocline, with a mixed layer above it; E, continuous density model; G, homothermal structure. In some cases the thermocline is so extended (B), that its lower boundary has not been determined. This type can be derived from the continuous density model (E), which has been modified by wave action and by currents into the epithermocline (C). If a homothermal water (G) is overflowed by a warmer water, the structure (F) may result, and if it is heated in calm weather, the type (D) is less saline, colder water, a temperature inversion (H) occurs. In waters, which are stratified by salinity and where effective mixing may occur in the various strata, several thermoclines (I) may be present.

**The changes of surface temperature are mainly determined by the following factors:**

- Insulation, or exposure to the sun, which depends upon the altitude of the sun and upon the cloudiness;
- Evaporation, which is mainly influenced by the humidity of the air and the wind speed;
- Convective transfer of heat, determined by sea air temperature difference and wind speed;
- Mixing of deep and surface water; and
- Transport by currents of waters with different temperature.



**Fig. 1 Some typical thermoclines**

## ***Influence of temperature on the reactions of fish***

The sense of temperature in fish seems to be well developed. Teleosts perceive and react purposely to a change in water temperature of 0.03°C. Fishes select a certain temperature because of its effect on movement (activity), and the temperature change may act on fish as;

1. A nervous stimulus;
2. A modifier of metabolic processes ; and
3. A modifier of bodily activity.

In addition, temperature of the environment also has a definite effect on the meristic characters of fish; e.g. the number of vertebrae and fin rays increases as the temperature decreases.

## ***Influence of temperature on spawning, and on development and survival of larvae***

The influence of the temperature of the environment on fish behaviour is at its most pronounced during spawning. But the temperatures prior to spawning are also highly significant, since they influence the ripening of the reproductive organs. It is observed that cold months preceding the spawning of cod (*Gadus callarias*) may have a considerable effect in delaying the maturation of the gonads. At temperatures below this range the ripening of the reproductive organs is delayed, and the opposite is the case at higher temperatures. Therefore, the past history of the temperature determines the arrival of stock at the spawning grounds.

## ***Influence of temperature on the abundance, migrations and shoaling of fish***

Nearly all fish stocks have specific optimum temperatures. Predictions of temperature, either statistical or synoptic, can be used for predicting the seasonal abundance of a given stock of fish. The concentration of food is temperature dependent, which makes the determinations of the 'optimum temperature' for a fish exceedingly complicated in a few cases.

The seasonal migrations, the shoaling connected with spawning, feeding etc., is controlled, either directly or indirectly, by temperature. The best fishing grounds and areas are frequently located on the boundary regions of two currents or in other areas of upwelling and divergence. Surface catches are also associated with a seasonal latitudinal change in surface temperature, particularly about the isotherms 12.8 – 18.3°C. The pattern of the diurnal vertical migration is affected, both directly and indirectly, through the concentration of food at the thermocline. The mackerel in the North Sea, seems to avoid water which has a temperature lower than 4 – 5°C.

The lowest and highest temperatures at which a fish may survive depend upon its previous acclimatization. Therefore, sudden changes of temperature are normally much more dangerous to fish than slower changes during which they have time to become acclimatized.

## ***Long term temperature changes and their influence on the distribution of species***

The long term temperature changes are not similar in all ocean, nor are they even similar in all parts of the same ocean. These changes are mostly determined by the changing patterns of major currents and by local meteorological conditions.

### **Long term temperature rise can cause the following**

- a. Change in the intensity of spawning.
- b. Changes in spawning grounds
- c. Change in the nursery and feeding grounds.
- d. An increase in the amount of food and in the amount of nutrient salts.
- e. The growth period is prolonged.
- f. shifted in the limit at which larvae can survive.

## **Light**

The importance of light to the behaviour of fish and their food is clearly demonstrated in various fishing methods, known even at the most primitive stage of fisheries technology.

## ***Absorption of light in the water***

The intensity of light below the water surface is controlled by absorption and scattering of light in the water. The absorption depends upon the wavelength of the light ; red light is absorbed much more rapidly than blue. The scattering of light against water molecules is rather insignificant. Actually the main factor affecting the scattering of light in the water is the amount and nature of the suspended matter present in the form of mineral suspension.

A simplified classification of water masses by optical properties, which thus are mainly dependent upon suspended matter present is given in table 1

**Table 1 Classification of water masses by optical properties**

<b>Water mass</b>	<b>Characteristics</b>
Oceanic, clear	Clear oceanic waters in low-productive areas (especially in low latitudes). Water colour 0 to 2 (Forel Scale).
Oceanic, normal	Medium-productive oceanic waters in medium and low latitudes. Water colour 2-5
Oceanic, turbid and Coastal, clear	High-productive oceanic areas, especially during plankton bloom. Tropical coastal waters, especially over deep shelves. Water colour 5 – 8
Coastal, normal	Normal, medium-productive coastal waters and waters over shallow shelves. Water colour 8 – 10.
Coastal, turbid	Estuarine and coastal waters during intensive plankton bloom and waters close to the Coast where much sediment has been whirled up by wave action. Water colour 10

Light intensities in different depths of water can either be measured directly, or the extinction of the light per unit distance is measured and the actual intensities computed from the light intensity on the surface and from the measured extinction. The simplest instrument for light measurements in water is the Secchi disc. The depth of disappearance of this disc is recorded.

### ***Response of fish to light stimuli***

Fish are known to respond to light stimuli between 0.01 and 0.001 Lux, depending upon previous adaption to light or darkness. The lowest light intensities which bring about the maximum response in fish are found to be between 50 and 200 Lux.

Visual capacity of the fish eye corresponds roughly to the capacity of the eyes of other higher vertebrates. However, owing to the turbidity of the water, frequently the visual range is only a few meters. The existence of colour vision in fish has been confirmed by the different reactions of fish to differently coloured nets. The fish can recognize the colour if the brightness of illumination exceeds a certain limit.

Fish can be either positively or negatively photo-tactic. Many commercial fish are attracted to artificial light during the night, a fact which is utilized in practical fishery. Hungry fish seems more easily attracted by light than fish which does not feed. Fish sometimes showed sudden upward movement towards the light immediately when switched on (shock effect), but after a few minutes they either disappear or descend.

The effect of artificial light on fish is also found to be influenced by other environmental factors and varies in some species with the time of day.

### ***Effects of light on spawning and survival of larvae***

Light has various real and apparent effects on the spawning of fish and on the larvae. The amount of light available can influence the maturity time of the fish. This is possibly a physiological effect and regulates the spawning time in several species of fish so that spawning takes place during the most favourable temperature conditions and hatching during the period when food is most abundant. Nevertheless, the indirect effects of temperature are usually difficult to separate from the light effects .

### ***Diurnal vertical migrations***

**Marine animals can be divided into the following six groups by the nature of their diurnal vertical migrations.**

- a. Pelagic species with daytime occurrence slightly above the thermocline; shows migration to surface layer at sun set; dispersion between surface and thermocline during the night; descent to above the thermocline by sunrise.
- b. Pelagic species with daytime occurrence in layers below the Thermocline; shows migration through thermocline into surface layers during sunset ; dispersion between surface and bottom during the night with bulk occurring above thermocline ; descent through thermocline into deeper layers during sunrise.

- c. Pelagic species with daytime occurrence in layers below thermocline; shows migration to thermocline during sunset; dispersion between thermocline and bottom during the night; descent into deeper layers during sunrise.
- d. Demersal species with daytime occurrence on or close to the bottom; shows migration and dispersal in to the water mass below (and occasionally also above) the thermocline during sunset; descent to the bottom during sunrise.
- e. Species which are dispersed throughout the water column during the day but which descend to the bottom during the night.
- f. Pelagic and demersal species without any distinct diurnal migrations.

### ***Other diurnal changes of fish behaviour***

There are several aspects of fish behaviour, e.g. feeding, response to current schooling etc., which change diurnally and may be directly or indirectly influenced by light. Also, in certain cases, the reactions of fish in respect other marine ecological groups may be influenced by light conditions. One of these examples is the relation between fish and phytoplankton.

Phytoplankton organisms are able to produce during the photosynthetic period, toxic substances, which cause the fish to avoid high concentrations of phytoplankton during the daytime. Therefore, the diurnal up and down migrations of fish in respect of light may also be influenced by phytoplankton. However, the behaviour of fish in respect of light also depends upon the turbidity of water. The behaviour is also affected by other environmental factors, e.g. by the temperatures, which usually are significant to the physiology of fish, as well as by the spawning habits. The light might also serve for certain species as a reference for orientation and might influence the response of fish to currents, the larvae of some fish swim against the current during the light period but drift passively with the current during darkness.

## **Currents in the sea, their measurement and prediction**

**The ocean currents are brought about by several more or less independent causes, which can be listed as follows:**

- a. The great permanent currents, the so-called gradient currents, e.g. the Gulf Stream are caused by the existence of horizontal density gradients or are maintained by the great permanent, more or less constant wind systems, especially by the trade winds.
- b. The day-to-day variable currents of surface layer are brought about by the variable winds. The changes in the atmospheric pressure have a direct minor influence upon the water movements.
- c. The vertically observable tides are, connected with horizontally appearing tidal currents which are caused astronomically and affected strongly by the bottom configuration in the near shore areas
- d. The wind waves also give rise to slow advective movement of surface waters.

In the coastal areas over the continental shelf, the tidal currents, wind currents - and water movements (caused directly by the changes in the distribution of atmospheric pressure) – and the ‘wave currents’ superimpose each other, while outside the continental shelf the permanent gradient currents and superimposed wind currents predominate.

The fishermen would be interested just in the current prevailing now at a specific time.

Tidal currents usually predominate on the continental shelf. However, in some semi-closed sea basins they are negligible, in which case the wind affected drift currents dominate.

### **The current boundaries can be**

- a. Dynamic, that is, convergences or divergences of more or less permanent current systems.
- b. Topographical, caused by the topography of the bottom or Coast,
- c. Combined eddy systems

The most usual locations of the current boundaries are;

- a. At meteorological fronts
- b. On continental slopes and
- c. Around islands, capes and banks (local boundaries)

Usually, the boundaries are demarcated by current rips, accumulation of floating foam, debris, modified waves, fog and sometimes roaring noises.

The boundaries of currents are extremely important to fisheries. In divergences the deeper nutrient rich water is brought into the surface layers where it causes a higher production of organic matter and an accompanied concentration of fish. The convergences cause dynamically a concentration of zooplankton and an accompanied concentration of fish. Pictorially, one may say that there is an accumulation of everything on the current convergences from plankton to fishermen. The current boundaries especially the convergences are associated with meanderings and eddy, with connected sinking and /or upwelling of deeper water.

## **Waves and their forecasting**

The three wave properties, the height, the length and the magnitude of wave motion at different depths in connection with different wave heights, are important from the fisheries point of view. These properties are functions of wind speed and duration, length of fetch, difference between sea surface and air temperature, presence of earlier waves and of swell, that is of waves arriving from distant generation areas and coastal areas and also of depth of water.

## **Behaviour of fish in currents**

Fishes respond to currents in various ways. The main reception organ is considered the lateral line. The direction of the fish in current usually heads to the current. If the current is strong, most fish head to the current, whereas in weak currents other directions and orientations occur. It might even be possible that fish in general use the currents for orientations in the sea. The movement of several species is affected both by light and by currents: in light the fish swim against the current, whereas in darkness they drift with it. A study of distribution of fish species also reveals that a permanent current with an average speed of more than one knot builds a distinct ichthyological boundary.

## **Current and survival of larvae**

Pelagic eggs and larvae are mostly exposed to the currents and, like other planktonic organisms, are carried around and dispersed by them. Eggs seem to adopt the specific gravity of the water into which they are deposited and in general, remain suspended in the same stratum until hatched. Mixing of different water masses and the energy exchange between the sea and the atmosphere change the properties of waters. Therefore, it can be expected that the mixing processes bring about changes in the depth of the deposited pelagic eggs ; by increase of density of the water the eggs will bloat up, by decrease they will sink. The use of cumulative wind data for the prediction of surface currents seems to be the only available means at present for estimation of the transport of eggs. It is also necessary, however, to take into account the changing, mixing conditions during transport.

The behaviour of adult fish in respect of currents, and other environmental conditions, depends on the physiological stage (e.g. the maturity) of the fish. Feeding pelagic fish usually drift with the water mass. Fish usually occurs in the zones of the eddies of currents where the fish are resting. Such local eddies are frequently found in the vicinity of offshore grounds and islands.

## **Influence of waves on fish**

The fact that fish avoid the upper layers during heavy weather is well known to fishermen. Also onshore-offshore movements of fish are, to a certain extent, affected by waves. Heavy storms usually cause lowering of surface temperature and influence the catch.

**The lowering of temperature can be brought about in two ways.**

- a. By mixing of warm surface water with deeper cold waters.
- b. By horizontal movements of surface waters bringing about intensified upwelling or sinking and thus causing vertical movements of waters of different temperature.

## **Chemistry of sea water**

### ***Dissolved salts and gases in sea water***

Seawater contains almost all elements in solution or in colloidal suspension in greater or smaller amounts. Normal oceanic water contains about 35 g salts per kg of water. Salinity can vary from almost 0 per thousand in fresh water to 40 parts per thousand (in Red Sea). Eestuarine areas and some semi-closed seas are brackish. Coastal areas have, on the surface, water with lower salinity, caused by run-off from the land areas. In offshore areas the salinity of the surface water is changed by precipitation, evaporation and occasionally also by ice formation.

The most important nutrient salts in seawater are the phosphates and nitrates. In deep water below the thermocline the concentration of phosphates is 2-4  $\mu\text{g.l}^{-1}$  and the concentration of nitrates is about ten times higher. From surface waters these nutrients are in some seasons nearly completely exhausted by the growth of phytoplankton. Thus the vertical transport of these nutrients by upwelling of deep water and by mixing determines in great extent the productivity of the sea.

Certain trace elements, such as iron and cobalt, also are important for phytoplankton growth and can at times and in certain areas, limit the organic production in the sea. The nutrient salts and trace elements thus affect the fish through the food chain. The seawater can be considered as a buffered solution, because of the presence of sufficient quantities of carbonates and borates. The carbon dioxide content and pH are therefore relatively constant, the pH varying in ocean water from 8.1 to 8.3 depending upon the temperature and salinity of the water and partial pressure of carbon dioxide in the atmosphere. The oceanic waters are in general rather well aerated. In principle the surface waters are saturated to 100 percent with oxygen

### ***Influence of salinity; and other chemical environmental factors on fish behaviour***

The salinity variations in the offshore areas are relatively small only but in coastal areas they are considerably larger due to the run off. The variations of salinity very often indicate the change in water masses or their stability conditions. The direct influence of salinity on most fish species can be considered minor only. The limits of the optimum salinity range, especially without any adaptation period to exceptional conditions, must be for any fish species much narrower than the utmost range of tolerance. Under normal conditions in the sea, the dissolved oxygen content of water does not become a limiting factor in the distribution of fish. However, in some cases, the oxygen might affect the behaviour of fish. Oxygen deficiency in the water plays a role as a retarding factor in the development of eggs.

### **Influence of the upwelling on the distribution of fish**

Upwelling occurs mostly in the eastern parts of the oceans along the coast and on the boundaries of currents. The primary reason for the upwelling is to be found in the relatively steady winds in the tropics and sub-tropics blowing along the coasts and or the wind divergences in the equatorial region. A secondary reason for the upwelling may be the local topography of the coast and the continental shelf in relation to the permanent ocean currents. These secondary reasons account usually for the upwelling in the western parts of the oceans.

**The upwelling phenomena of the low oxygen content can be divided into two groups:**

1. Upwelling in presence of a (tropical) subsurface oxygen minimum layer;
2. Upwelling of bottom waters from which the oxygen has been consumed by the organic sediments.

### **Nature of the bottom in relation to the fish and fishing**

The knowledge of depth of water in a given location is of the utmost importance in most fisheries. This knowledge is obtained partly from the available navigational charts and partly from the actual soundings. In addition to the knowledge of depths, the nature of the bottom is equally important for the fishermen, especially for trawling purposes.

Most fish concentrations depend both on depth of water and on distance from the Coast. No generally valid data can, however, be presented, since the species show rather great local and seasonal variations. Usually the smaller and younger individuals are found in

shallower water than the larger and older ones. Each of the truly demersal fish species has a preference for a particular type of bottom, probably directed by specific requirements for food, protection and spawning. The fish food in the bottom – the benthos – varies considerably in quantity and in species composition from one type of bottom to another. Also the depth of water and the hydrographical conditions close to the bottom are significant to the benthos.

## **Relation between fish and its food in the sea**

The food relations in the sea are, of course, in reality much more complicated. The composition of food taken varies by age of the species, location and season and is largely determined by the availability of food. The feeding behaviour of fish varies considerably from species to species. In the sea sometimes there is severe competitions for food and living space between different species. This competition is largely influenced by changes of hydrographical conditions, which may favour one and hinder other species in a given region.

## **Relation between plankton and fish**

The production of organic matter by phytoplankton is the main factor for the existence of other groups of life in the marine biotopes. There is a relation between the amount of basic organic production by phytoplankton and the size of the population of other marine organisms that occupy the lower links of the marine food chain. The relation is often indirect and correlation is difficult to trace because of time lags and transport by currents. A relationship can be demonstrated easily when especially well defined natural regions or semi-enclosed seas are considered. Phytoplankton can serve in some cases directly as food for fish larvae and for some to the smaller economically exploited species of fish, in which cases the quantitative relation can be recognized in a limited area. Since zooplankton is considered directly or indirectly the main food for fish, especially for pelagic fish, this relation has been most sought for. It is obvious that the pelagic fish species are largely dependent on the plankton for food. Therefore, the behaviour and distribution of zooplankton greatly influence the behaviour of pelagic fish, such as herring.

The aggregation of fish on a high concentration of plankton occurs only in specific conditions and is, for various reasons, variable in space and time. The reasons are the relatively rapid vertical migrations of plankton organisms, the development of patches, grazing down of patches and transport by currents.

## **Influence of meteorological factors**

The meteorological factors are the primary causes for the changes in hydrographical conditions in the sea, an indirect correlation between the behaviour of fish and the meteorological factors can often be found, although mostly the direct causative factors are to be sought in the hydrographical parameters. The behaviour (horizontal and daily vertical migrations, aggregations, dispersal, etc.) and consequent accessibility of fish are determined by a multitude of environmental factors, which in turn are directly influenced and or determined by the meteorological conditions.

Long-term series of hydrographic data, collected at certain key points, are sometimes used in fisheries for understanding the changes in the environment and thus in the factors

affecting the fish and the fisheries. The identification and tracing of particular water mass movements are necessary for the estimation of the movement of pelagic fish with and within a given water mass (current) boundaries, where aggregations of fish are usually expected to be found, and also for estimation of the conditions of survival of larvae of given species.

The data on the locality for the best catch, when correlated with information on optimum water temperature for tuna, configuration of ocean bottom, and type of ocean current, have proved useful in indicating to fishing vessels the situation under which the long-line gear can be operated to maximum advantage.