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Vertical Water Circulation and Seasonal Migrations of Fish in the Eastern Atlantic

By

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Summary

The paper discusses certain characteristics of the seasonal migrations of the main commercial fishes in relation to one of the most important hydrodynamical factors producing a great effect upon all the essential features of hydrographic regime of the West African coastal areas, i.e. in relation to verical water circulation.

To characterize vertical sea water movements we have used the method of surface current speed calculation, information on these currents within the area discussed being most complete. As a result, mean vergences charts covering a number of years have been plotted for all the four seasons. The chart of seasonal fish migration is based on special publications and on the data obtained by AtlantNIRO research vessels.

Along the west African coast of the Atlantic there are quasistationary areas of upwelling and fall of the sea timed to the zones of surface current divergences and convergences. These areas are more or less stable in size but their vertical movement intensity has considerable seasonal fluctuations. During the winter period maximum intensities in vertical circulation are observed above the 30° parallels in both hemispheres. In summer vertical movement intensity shifts from the high latitudes towards the equator. This is connected with a conjugation of the atmospheric processes in both hemispheres and, in particular, with a simultaneous increase in the Azores and South-Atlantic barometric maximums.

Seasonal migrations of most of the commercial fishes inhabiting West African waters are in agreement with the regularities of seasonal changes in vertical movement intensity.

In spring and summer in the northern hemisphere, when an intensification of vertical circulation in the subtropical and tropical areas, especially in the open sea, is observed, migrations (feeding and spawning) of most of the commercial fishes in both hemispheres are directed towards the open sea.

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In autumn and winter in the northern hemisphere, when there is a decrease in vertical circulation in tropical and subtropical areas, the fish migrate towards the shore where vertical movement intensity is more pronounced than in the open sea.

A number of works have been published by now indicating the relation between the seasonal movements of certain commercial fishes inhabiting West Africa areas and the vertical circulation of water.

The whole picture of this relation, however, remains uncertain due to the fragmentary character of the data on vertical water circulation and the related migrations of fish.

The main purpose of our studies has been as follows:-

1. To find out the seasonal characteristics of vertical water circulation in the Eastern Atlantic (36°N to 36°S).
2. To plot charts of seasonal migrations of the important commercial fishes.
3. To determine the relation between seasonal migrations and changes in the direction and intensity of vertical water movements.

It is well known that the upwelling and the ensuing high biological production in some areas of the Eastern Atlantic are caused by the driving effect of the trade-winds and divergences in the field of surface current speeds.

Therefore, to estimate vertical movements use was made of the method for calculating the divergence of surface current speeds by the formula: $\mathrm{div.}V = \partial u/\partial x + \partial v/\partial y$,

where V is the vector of the horizontal surface current speed.

Data on the currents were taken from (1-4); fish seasonal migration charts are based on (5-15) and on the data obtained by AtlantNIRO research vessels.

This information allowed to plot charts of divergences of surface current speeds and two charts of fish migrations for autumn - winter (September - February) and spring - summer (March - August) seasons.

The results thus obtained supplemented our present knowledge of the pattern of vertical water circulation and provided a better insight into the fundamental laws governing fish migrations in the area discussed.

An analysis of the divergence charts shows that during the autumn-winter period (September-February) a maximum intensity of vertical circulation is observed in the open sea above the thirties parallels and along the coast (Fig. 1 A,B).

For instance, large upwelling areas are found off the coast between 5°-12°N and 18°-30°S.

During the spring-summer period maximum intensities of vertical movement are found to shift from the high latitudes towards the equator and away from the coast (Fig. 2 A,B).

A remarkable feature of the summer period is the formation of a nearly uninterrupted strip (the areas bounded by the $+50 \cdot 10^{-8} \mathrm{sec}^{-1}$ line) of intensive[x] upwelling in the open sea all along the African coast.

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[x] We must specify that the term 'intensive' is here applied to divergences exceeding $\pm 50 \cdot 10^{-8}$ sec^{-1}. When comparing divergence charts with those of water temperature distribution the effects of vertical circulation are manifested in the water temperature anomalies beginning from this value of divergence.

It is interesting to note that the quasi-synchronous strengthening (judging by the value of vergences) of vertical circulation exists in the tropical and subtropical areas of both hemispheres, and that is undoubtedly connected with a conjugation of their atmospheric processes and, in particular, with simultaneous higher barometric maximums in Azores and South-Atlantic areas (16).

As for migrations of commercial fishes the following regularirities have been observed:

In spring and summer in the northern hemisphere, when an intensification of vertical circulation in the subtropical and tropical Atlantic areas is observed, the migrations of commercial fishes (sardines, mackerel, horse mackerel, hake) are directed towards the open sea and to the upwelling areas on the shelf (Fig. 2 A,B,C).

And conversely during autumn and winter the fish move to the coast where, at that period, vertical circulation is more pronounced than in the open sea (Fig. A,B,C). Fishing efficiency at that time sharply increases.

The migration process is of a one-sided character for both hemispheres, and this apparently is in agreement with the seasonal changes of vertical water movements.

It should be noted that the food of the fishes in question is plankton, fish and squids, concentrations of which are usually timed to upwelling zones or to their periphery (10-15).

All this suggests the conclusion that the observed conjugation of vertical circulation processes forms feeding fields providing more favourable trophic conditions in the open sea areas in spring and summer (March-August), and in the coastal areas in autumn and winter (September-February).

This obviously accounts for the uniform direction in the seasonal migrations of most of the commercial fishes in the Eastern Atlantic.

The plotted vertical circulation charts are in agreement with the studied tuna migrations.

According to the available data (10-13) the small yellowfin tuna from the central part of the Gulf of Guinea and the large tuna from the Angola stock move, by summer, to an area west off Cabo Verde - 20°W (Fig. 1C,2C). The chart in Fig. 2B shows an area of intensive upwelling. During a drop in upwelling (October-November) they return to the Gulf.

Small tuna from the eastern part of the Gulf of Guinea migrate in August (the time of an initial upwelling drop in the north-western part of the Gulf to 15°-20°S (Fig.1A,C) where vertical circulation grows.

Another migration route of the large tuna from the Angola stock passes westward from Angola, along the divergence in the Southern Gulf (10°S) and is timed to the period of its intensification in the northern hemisphere winter (Fig.1B,C).

It should be mentioned, in conclusion, that the periods of tuna migrations north and south from the equator coincide with the time when commercial fishes set off for the open sea.

List of Illustrations[1]

Fig. 1 - Distribution of surface current speed divergences (in terms of $10^{-8}sec^{-1}$) and fish migration chart for the Eastern Atlantic, September to February.

A - Divergences distribution in September-November

B - Divergences distribution in December-February

C - Fish migration chart

1 - hake; 2 - sardines; 3 - horse mackerel;
4 - mackerel; 5 - small yellowfin tuna; 6 - commercial concentrations of yellowfin tuna; 7 - fish larvae;
8 - large yellowfin tuna; 9 - squids.

Dotted interrupted arrows are for the supposed migration routes. Areas of upwelling in Fig. A and B are shaded.

Fig. 2 - Distribution of surface current speed divergences (in terms of $10^{-8}sec^{-1}$) and fish migration chart for the Eastern Atlantic, March to August.

A - Divergences distribution in March-May

B - Divergences distribution in June-August

C - Fish migration chart.

Conventional marks are the same as in Fig. 1

[1] To be shown as slides.

Literature used

1. Hydrometeorological charts of North Atlantic Ocean. UNGS, VMF, 1956.

2. Hydrometeorological Charts of South Atlantic Ocean. UNGS, VMF, 1959.

3. Atlas of Surface Currents of South Atlantic Ocean. Hydrographic Office U.S.Navy, Washington 1947.

4. Current Atlas of North Atlantic Ocean, Hydrographic Office U.S. Navy, Washington, 1947.

5. Yu.A. Komarov, 1962, South Africa Sardine (Sardinops ocellata), Trudy BaltNIRO, ser. IX.

6. Yu.A.Komarov, 1964. Some data on Reproduction of Horse Mackerel (Trachurus trachurus L.) from South-West Africa areas, Trudy AtlantNIRO, ser. XI.

7. K.G. Kukhorenko and Yu.Komarov, 1966. Commercial Fishes in Tropical East Atlantic Ocean, Kaliningrad.

8. A.G. Novozhenin and A.G. Staroselskaya, 1964. On Biology of Mackerel from the Coastal Areas of North-West Africa, Trudy AtlantNIRO, ser. XI.

9. S.M. Overko, 1964. On Fisheries Biology of Horse Mackerel from the Coastal Areasof North-West Africa, Trudy Atlant-NIRO, ser. XI.

10. V.L. Zharov, 1966. Dependence of Distribution of Tuna Concentrations upon the Water Oceanographical Structure in some Tropical Areas of the Atlantic Ocean. Trudy VNIRO, v.X.

11. V.L. Zharov, 1967. On Shifting of Concentrations and Localities of Yellowfin Tuna (Tunnus albacores Bonnaterre) Stocks in the Atlantic Ocean. Report of the Committee on Mackerel, ICES Meeting, Doc. No.55.

12. Jager, B., Nepgen, V., van WYk R., 1963. A Preliminary Report on South African West Tuna. Dep. Comm. and Ind., Deep Sea Fish. Invest., Rep. No.47.

13. Le Queen J.C.Poinsard,F. Troadec J.P., 1965. La pêche de l'albacore (Neothunnus albacores Bonnaterre) dans la zone orientale de l'Atlantique-Intertropical (Etude préliminare). Office de la Rech. Scient. et Technique Outre-Mer. Centre de Point-Noire. Oceanographie, Document No.263-S.R.

14. Postel, E. 1955. Recherches sur l'echologie du thon a negeoires jannes, Neothunnus Albacore (Lowe), dans l'Atlantique Tropico-Oriental. Bull. Inst. Franc. Afrinoire, (A), 17(1).

15. Furnestin, M.L., Claude, M., 1966. Plancton et Poissons. Relations quantitives entre plancton et poissons. Revue des travaux de l'Institut des Pêches Maritimes, tome XXX, fasc. 2 et 3.

16. L.V. Kool, 1965. Barometric Field of the Trade Wind Zone of the Atlantic Ocean and its Transformation with the Height, Oceanography, iss. 5.