# ON SOME PECULIARITIES IN OUR COASTAL WINDS AND THEIR INFLUENCE UPON THE ABUNDANCE OF FISH IN INSHORE WATERS.

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[With Plates I. - VI.]

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IN compiling the statistical evidence relating to the quantity of fish obtained from various coastal waters, I found that the total catches, though fluctuating somewhat, are on the whole on an increase. The markets are now receiving a good deal more fish than formerly, and that so far is satisfactory; but such an increase is not in itself a proof of a greater abundance of fish on this coast, and we know that the development of new grounds and an increased number of men may have such an effect. It would seem that the *mode* of capture has remained almost unaltered for a very long time, and this facilitates a comparison between past and present as regards the result of the average man's work.

It is fortunate that the Departmental Inspectors stationed within some principal fishing waters, have kept a monthly record of the number of men employed and the bulk of their catches, and it is possible for each of these localities to determine *the average catch per man* for each month and for the year.

The following table records the average catch per man each month within all the fishing waters for which reliable and detailed data is available, and the figures convey some very interesting information :—

Table I.—Shewing the Average Catch per man (in baskets equal 75lbs) each month.

| Waters. | Jan. | Feb. | Mar. | Apr. | May | Jun. | July | Aug. | Sept. | Oct. | Nov. | Dec. | Avr. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clarence River ... ... | 27·5 | 26·1 | 29·8 | 40·4 | 35·9 | 25·4 | 25·3 | 25·6 | 30·6 | 29·6 | 31·8 | 23·8 | 29·1 |
| Port Macquarie ... ... | 13·4 | 14·5 | 13·5 | 20·2 | 17·4 | 14·5 | 13·7 | 14·0 | 12·4 | 13·6 | 14·6 | 13·4 | 14·9 |
| Cape Hawke ... ... | 16·6 | 20·7 | 20·9 | 16·7 | 19·0 | 18·6 | 20·2 | 18·3 | 17·3 | 21·9 | 17·1 | 13·5 | 18·4 |
| Port Stephens ... ... | 12·0 | 11·7 | 16·3 | 20·5 | 20·1 | 20·1 | 16·6 | 13·1 | 10·0 | 9·4 | 8·7 | 10·4 | 13·8 |
| Lake Macquarie ... ... | 13·2 | 14·2 | 16·7 | 14·6 | 15·6 | 13·5 | 12·8 | 12·8 | 14·5 | 16·3 | 16·4 | 12·6 | 14·5 |
| Tuggerah Lakes ... ... | 12·8 | 16·1 | 17·2 | 13·3 | 17·5 | 21·7 | 17·0 | 11·9 | 10·5 | 12·5 | 11·3 | 10·1 | 14·2 |
| Lake Illawarra ... ... | 19·3 | 19·1 | 25·3 | 20·6 | 25·0 | 20·6 | 20·6 | 22·9 | 23·9 | 15·4 | 12·2 | 11·1 | 19·4 |
| Shoalhaven River ... | 8·5 | 9·6 | 11·1 | 11·5 | 9·8 | 13·5 | 14·5 | 12·8 | 7·9 | 9·1 | 8·6 | 6·8 | 10·6 |
| Clyde River ... ... | 3·5 | 4·7 | 16·7 | 16·9 | 7·9 | 11·4 | 8·7 | 5·8 | 5·7 | 8·0 | 6·9 | 3·5 | 8·3 |
| Pambula District ... | 7·4 | 15·5 | 15·4 | 13·7 | 10·4 | 7·0 | 7·0 | 8·8 | 9·6 | 15·6 | 14·4 | 10·0 | 11·1 |
| Average for all waters... | 13·4 | 15·2 | 18·3 | 18·8 | 17·9 | 16·6 | 15·6 | 14·6 | 14·2 | 15·1 | 14·2 | 11·5 | |

**Relative Richness of the Different Waters.**—From the last vertical column it will be seen that the average monthly catch varies considerably in different localities; the three most southern waters are the poorest as far as bulk goes, while Lake Illawarra is second best. But in connection herewith, it must be remembered that a small quantity of "choice" fish is equal to much larger quantities of inferior quality; also that with existing modes of conveyance the fish from distant places realises relatively less in the markets than what is brought a shorter distance.

**Seasonal fluctuation in the abundance of fish.**—From the table it will be seen also that the catch is much greater at some periods of the year than at others, although the individual waters show differences in this respect. This exceeding the local average are shown above the line, and will best be seen from Diagram A (*Plate* I.), where all catches the others below. The richest season of the year is March to May, with April as a climax. This coincides with the sea-mullet season, and the secondary climax in October is mainly due to "prime" fish. The monthly (or seasonal) changes in the richness of the catches do not in any way demonstrate a corresponding fluctuation in the actual abundance of fish. It is merely an indication as to when the fish congregate in convenient places for the nets to be



hauled round them, as during the migrating periods, or an apparent scarcity is felt when the fish are scattered and in places more or less inaccessible for nets.

**Annual fluctuation in the abundance of fish.**—It is from a comparison of the yearly average catches that the important evidence is obtained as to whether our fisheries are improving or not, and the primary data relating thereto has been recorded in Table II.

Table II.—Showing the total catch each year and number of men employed.

A.—YEARLY CATCH (in Baskets equal 75 to 80 lbs.)

| Waters. | 1897 | 1898 | 1899 | 1900 | 1901 | 1902 | 1903 | 1904 | 1905 | 1906† |
|---|---|---|---|---|---|---|---|---|---|---|
| Clarence River ... | ... | ... | ... | .. | ... | ... | 17039 | 24082 | 24164 | 23040 |
| Port Macquarie ... | . . | ... | ... | ... | ... | ... | 2843 | 3030 | 2105 | 1185 |
| Cape Hawke ... ... | ... | ... | ... | 7673 | 10521 | 15099 | 13397 | 10592 | 11661 | 8922 |
| Port Stephens ... | ... | ... | ... | 5029 | 8671 | 10436 | 19247 | 14843 | 16613 | 11754 |
| Lake Macquarie ... | 10930 | 12210 | 11539 | 9861 | 10761 | 10863 | 11627 | 13615 | 13711 | 8387 |
| Tuggerah Lakes ... | 9343 | 6259 | 4476 | 6615 | 8747 | 12524 | 11165 | 8226 | 6895 | 6918 |
| Lake Illawarra ... | 8305 | 4631 | 8971 | 5327 | 6354 | 8444 | 10841 | 7950 | 6630 | 5105 |
| Shoalhaven River ... | ... | ... | ... | ... | ... | 4546 | 5752 | 5667 | 3495 | 4019 |
| Clyde River ... ... | ... | ... | ... | ... | ... | 1937 | 1736 | 1025 | 1519 | 1689 |
| Pambula ... ... | ... | ... | ... | ... | .. | 843 | 926 | 1249 | 992 | 915 |

B.—NUMBER OF MEN.*

| Waters. | 1897 | 1898 | 1899 | 1900 | 1901 | 1902 | 1903 | 1904 | 1905 | 1906† |
|---|---|---|---|---|---|---|---|---|---|---|
| Clarence River ... | ... | ... | ... | ... | ... | ... | 36 | 68 | 83 | 96 |
| Port Macquarie ... | ... | ... | ... | .. | ... | ... | 15 | 17 | 12 | 6 |
| Cape Hawke ... ... | ... | ... | ... | 40 | 39 | 48 | 63 | 55 | 67 | 68 |
| Port Stephens ... | ... | ... | ... | 21 | 25 | 49 | 97 | 121 | 137 | 95 |
| Lake Macquarie ... | 59 | 65 | 65 | 65 | 58 | 53 | 73 | 80 | 85 | 79 |
| Tuggerah Lakes ... | 51 | 52 | 39 | 33 | 35 | 54 | 65 | 53 | 54 | 40 |
| Lake Illawarra ... | 32 | 29 | 34 | 27 | 24 | 36 | 33 | 34 | 41 | 36 |
| Shoalhaven River ... | ... | ... | ... | ... | ... | 32 | 48 | 51 | 22 | 21 |
| Clyde River ... ... | ... | ... | ... | ... | ... | 13 | 14 | 14 | 21 | 13 |
| Pambula ... ... | ... | ... | ... | ... | ... | 5 | 6 | 8 | 11 | 10 |

* These figures represent in each case the average of the monthly returns.
† Ten months only.

The average catch per man per month for each year and each water has been recorded in Table III., where the relative difference in richness between the various localities

Table III.—Showing Monthly Catch per Man (baskets).

| Waters. | 1897 | 1898 | 1899 | 1900 | 1901 | 1902 | 1903 | 1904 | 1905 | 1906 | Avr. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Clarence River ... ... | ... | ... | ... | ... | ... | ... | 39·3 | 29·4 | 24·3 | 24·1 | 29·3 |
| Port Macquarie ... ... | ... | ... | ... | ... | ... | ... | 15·4 | 14·7 | 14·7 | 16·4 | 15·3 |
| Cape Hawke ... ... ... | ... | ... | ... | 15·9 | 22·8 | 26·5 | 17·7 | 16·0 | 14·6 | 13·1 | 18·1 |
| Port Stephens ... ... | ... | ... | ... | 19·7 | 28·6 | 19·4 | 16·5 | 10·2 | 10·1 | 12·4 | 16·7 |
| Lake Macquarie ... ... | 15·5 | 15·4 | 14·7 | 12·7 | 15·4 | 16·9 | 13·2 | 14·2 | 13·5 | 11·0 | 14·3 |
| Tuggerah Lakes ... ... | 15·2 | 10·1 | 9·5 | 17·0 | 20·9 | 19·3 | 15·4 | 13·1 | 10·7 | 17·3 | 14·9 |
| Lake Illawarra ... ... | 21·8 | 13·3 | 22·3 | 16·7 | 22·2 | 19·5 | 27·2 | 19·3 | 13·3 | 14·1 | 19·0 |
| Shoalhaven River ... ... | ... | ... | ... | ... | .. | 11·9 | 10·0 | 9·3 | 13·1 | 18·7 | 12·6 |
| Clyde River ... ... ... | ... | ... | ... | ... | ... | 12·3 | 10·4 | 6·9 | 6·1 | 13·5 | 9·8 |
| Pambula District ... ... | ... | ... | ... | ... | ... | 15·3 | 12·3 | 13·5 | 7·2 | 9·4 | 11·5 |

is again apparent. But the object of this table is to show how the abundance of fish fluctuates from year to year within the same water, and litte assistance is required to follow the general trend of this evidence. It is apparent that during the last few years there has been a general decline in the catches, culminating about 1905; about 1901 or 1902 there was a general abundance of fish, and again a shortage about 1898. It should here be noted that as all the waters show an almost simultaneous increase and decrease it is useless to suggest that inter-migration from water to water has anything to do with this.

In order to obtain a still more definite idea as to the evidently periodic fluctuation in the abundance of fish on the coast, I have reduced this evidence still further by the only two methods possible, Table IV., and Table V., and the result is in both cases the same (Diagram B.). We have before us very conclusive proof of the existence of cycle-like fluctuations embracing numbers of years in each period, and this in itself, is as far as it goes a discovery of wide importance.

Tables IV. and V.—Showing Average Monthly Catch per Man.

| Waters. | 1897 | 1898 | 1899 | 1900 | 1901 | 1902 | 1903 | 1904 | 1905 | 1906 |
|---|---|---|---|---|---|---|---|---|---|---|
| All Waters recorded ... ... | ... | ... | ... | ... | ... | ... | 17·7 | 14·7 | 12·8 | 15·5 |
| Eight Waters ... ... ... | ... | ... | ... | ... | ... | 17·6 | 15·3 | 12·8 | 11·1 | 13·3 |
| Five Waters .. ... ... ... | ... | ... | ... | 16·4 | 22·0 | 20·3 | 18·0 | 14·6 | 12·5 | 13·3 |
| The Three Lake Waters ... ... | 17·5 | 12·9 | 15·5 | 15·5 | 19·5 | 18·6 | 18·6 | 15·5 | 12·5 | 13·3 |
| Clarence River and P. Macquarie | ... | ... | ... | ... | ... | ... | 27·4 | 22·1 | 19·5 | 23·5 |
| Cape Hawke and Port Stephens | ... | ... | ... | 17 8 | 25·7 | 23·0 | 17·1 | 13·1 | 12·4 | 12·7 |
| Lakes Macquarie, Tuggerah and Illawarra ... ... ... | 17·5 | 12·9 | 15·5 | 15·5 | 19·5 | 18·6 | 18·6 | 15·5 | 12·5 | 13·3 |
| Shoalhaven, Clyde, and Pambula Rivers ... ... ... ... | ... | ... | ... | ... | ... | 13·2 | 10·9 | 9·9 | 8·8 | 15·6 |

The next stage in my inquiry has been to seek a satisfactory explanation of these fluctuations, and primarily to determine whether they are due to natural causes, or more or less to the interference of man. A great deal of work has been expended in connection herewith, and it is only



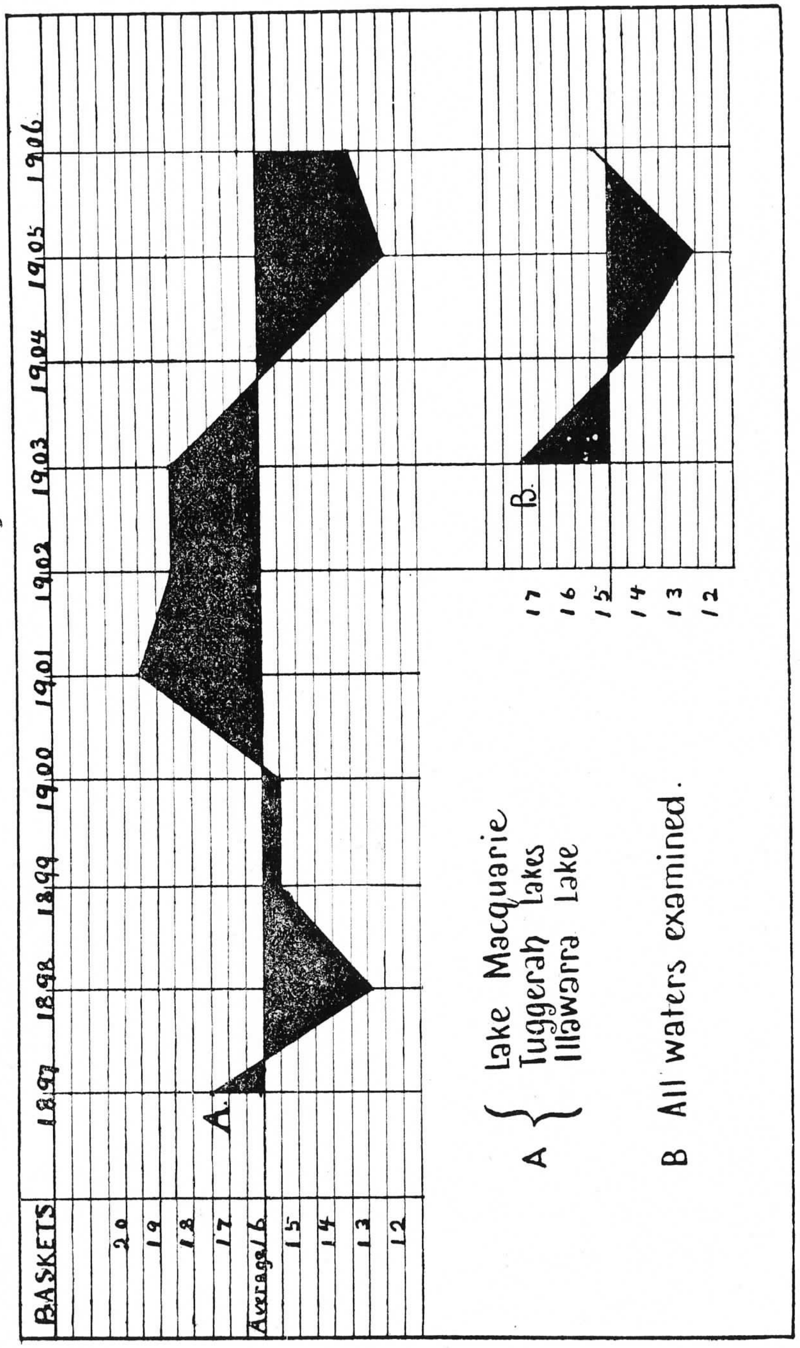



DIAGRAM B:— Fluctuation in Abundance of Fish after several unsuccessful attempts that what would seem a highly satisfactory result has been attained.

It is obvious that before the action of the fishermen through the capture of too great quantities, or by excessive destruction of young fish can be held directly responsible, it is necessary to find in the changes of men's numbers or methods, a fluctuation corresponding in some way with the "ups and downs" in the abundance of fish, as demonstrated in Table IV., and as such a correspondence is not apparent, it becomes necessary to look for the explanation in other directions.

As to the influence of physical conditions upon the abundance of fish, I first of all made search for periodicity in changes, and herein I received most valuable assistance from the present Commonwealth Meteorologist Mr. Hunt, who until recently was in charge of the local sub-department. I examined large quantities of records having reference to temperature, rainfall and winds, and this study was I think in itself of some value owing to the disclosure of certain meteorological phenomena that resulted, but before referring to these and their bearing upon the abundance of estuarine food-fishes in our waters, it is desirable to shortly mention such principal features in the life of these fishes as are likely to be seriously affected by prolonged climatic changes.

Two principal features in the life-history of most of our food-fishes have been fully demonstrated through some of my earlier investigations, they are in short:—

1. That the shoals of full grown fish that at certain seasons of the year are seen to enter our estuaries or leave them, are natives of this coast, they do not come from "foreign parts" nor do they leave for such places. They are our all own, and travel periodically northwards, mainly in connection with their reproduction.



2. The bulk of the spawning takes place in proximity to the open ocean where the floating eggs (and afterwards the young larvæ) are at the mercy of the coastal currents. These flow as a rule in a southerly direction past the headlands and the mouths of the estuaries, and thus it happens that the "pelagic stage" is carried back towards the locality whence the parents came. The old fish are replaced by young which remain in the estuary until ready to migrate and spawn; then the process of redistribution is repeated.

Analogous cycles of migration and drift have been found to exist in other parts of the world, notably in the North Sea, and there is reason to believe they are, with modifications, quite universal in connection with the distribution of fishes having pelagic eggs. It is well known that but an infinitely small percentage of the millions of eggs that a single fish may produce, will succeed through the various stages of development and attain maturity, and it is also very apparent that this great loss or destruction takes place mainly during the least protected stages—that is while the eggs or the young fry are drifting helplessly about in the open waters. Under these circumstances it would seem that the favourableness or otherwise of certain physical conditions, notably the currents, should in a general way afford an index to the relative successes and losses of a hatching season, and it is in this direction that my inquiries have succeeded through indirect channels, *i.e.*, the winds.

**Some peculiarities in our Coastal Winds.**—Through the courtesy of Mr. Hunt, I have had an opportunity of examining the Sydney anemometer records for the last twenty-four years. They contain parallel sets of figures representing respectively (1) the number of hours the winds blew from each point of the compass, and (2) the corresponding number of miles that the atmosphere has travelled in the different directions. These automatically taken records have been totalled up each month, and to that extent I found the material conveniently prepared. It seems customary in most meteorological work to attach greatest importance to the *duration* of the "blow" (prevailing winds) and the *total mileage*, which is proportionate to the *expended energy* is frequently disregarded. That point of view might be quite good in some instances, and the prevailing wind is often gentle and harmless, but the dominating wind which travels a greater number of miles in a shorter time is also of consequence, on account of its greater violence and powers of destruction.

The method adopted in my treatment of the winds, and also its justification may be seen from the following illustrations: If in the centre of an imaginary borderless sheet of perfectly smooth ice were placed a 'feather-light' object and all friction could be disregarded, the successive winds from different points would carry this object about from place to place. The distance traversed in each direction would be equal to the mileage of each blow, and with a complete record of this mileage, it is easy at any moment to determine the whereabouts of the object. The final resting place of the latter at the end of a certain period would, in its relation to the starting point, be a means of discovering the general drift of the atmosphere during that time. The distance and direction would be expressed respectively in miles and degrees, and it would be easy to compare one period with another.

The feather-light object represents the atmosphere itself (or a particle), and the 'borderless' ice a sufficient section of the surface of the globe; the starting point or centre is in this case identical with the wind recorder, *i.e.*, Sydney Observatory.



From the twenty-four years' records of winds I first determined all necessary averages or *normals* as follows:—

(1) The average total mileage from each cardinal point for each calendar month, and for the year.

(2) The mean atmospheric drift, or the resultant wind for each of the same periods.

The tables and diagrams prepared in connection with these determinations are too voluminous to be included in this paper, and only the final results are given.

Table VI.—Showing amount of Wind in Miles, from each Point of the Compass and for each Month (Normals).

| Month. | S. | S.W. | W. | N.W. | N. | N.E. | E. | S.E. | Total. |
|---|---|---|---|---|---|---|---|---|---|
| Jany. ... | 1655 | 433 | 344 | 172 | 296 | 2358 | 1355 | 995 | 7608 |
| Feby. ... | 1349 | 347 | 263 | 121 | 283 | 2018 | 1112 | 1061 | 6554 |
| March ... | 1345 | 434 | 422 | 230 | 318 | 1618 | 1022 | 1083 | 6472 |
| April ... | 1157 | 844 | 1093 | 398 | 354 | 957 | 510 | 467 | 5780 |
| May ... | 950 | 994 | 1794 | 573 | 312 | 432 | 192 | 359 | 5606 |
| June ... | 624 | 1008 | 2884 | 982 | 414 | 223 | 186 | 287 | 6608 |
| July ... | 807 | 1139 | 2937 | 876 | 365 | 191 | 239 | 296 | 6850 |
| August... | 999 | 930 | 2351 | 816 | 383 | 506 | 304 | 362 | 6651 |
| Sept. ... | 873 | 812 | 1815 | 683 | 452 | 974 | 533 | 456 | 4961 |
| Octr. ... | 1274 | 674 | 1210 | 673 | 463 | 1501 | 900 | 704 | 7399 |
| Novr. ... | 1516 | 508 | 528 | 316 | 364 | 1999 | 1086 | 922 | 7239 |
| Decr. ... | 1590 | 354 | 392 | 272 | 333 | 2121 | 1423 | 959 | 7444 |
| Total ... | 14139 | 8477 | 16033 | 6112 | 4337 | 14898 | 8862 | 7951 | 79172 |

In Table VI. is shown the *average* amount of wind (in miles) that blows from each of the cardinal points each month, and the *average totals* for the year. As to the latter, it will be seen that the southerly is essentially a summer wind, strongest in December and January, and of least importance in the winter. This wind is third in importance of all the eight winds, and exceeds 14,000 miles a year. The south-westerly is the reverse of the southerly and fifth in importance with about 8,500 miles. The westerly is also a winter wind (in excess from May to June) and is the first in importance with about 16,000 miles a year. The north-westerly is also a winter wind and seventh in order with about 6,000 miles. The northerly is fairly generally distributed throughout the year, and is of least importance with about 4,300 miles. The north-easterly is a typical summer wind and is reduced to a minimum in July. It is second in importance with about 14,000 miles. The easterly resembles the former, it is generally one month earlier in its fluctuations, and stands number four in importance with about 8,800 miles. The south-easterly is also a summer wind and is number six in order of importance with about 8,000 miles for the year.

We have three primary winds, *West*, *North-east* and *South*, with from 16,000 to 14,000 miles each, and the others are of secondary power. The total amount of wind that passes over one fixed point during a normal year is slightly more than 79,000 miles, and is fairly evenly distributed over the different months.

In order to discover the final result from the action of the monthly winds in analogy with the movements of the feather-light object already referred to, I have compared the opposing forces (north and south, east and west) and substracted the smaller from the larger. The four remaining balances represent the total "drift" energy for the month, and have been recorded in Table VII.

Table VII.—Showing the four dominating Winds (in miles) for each month (Normals).

| Month. | S. | S.W. | W. | N.W. | N. | N.E. | E. | S.E. |
|---|---|---|---|---|---|---|---|---|
| January ... ... | 1359 | ... | ... | ... | ... | 1925 | 1011 | 823 |
| February .. ... | 1066 | ... | ... | ... | ... | 1671 | 849 | 941 |
| March ... ... | 1027 | ... | ... | ... | ... | 1184 | 600 | 854 |
| April ... .. | 803 | ... | 583 | ... | ... | 113 | ... | 69 |
| May ... ... | 638 | 562 | 1602 | 215 | ... | ... | ... | ... |
| June ... ... | 210 | 785 | 2698 | 695 | ... | ... | ... | ... |
| July ... ... | 442 | 948 | 2698 | 580 | ... | ... | ... | ... |
| August ... ... | 616 | 424 | 2047 | 453 | ... | ... | ... | ... |
| September .. | 421 | .. | 1282 | 228 | ... | 162 | ... | ... |
| October ... ... | 811 | ... | 310 | ... | ... | 827 | ... | 31 |
| November ... | 1152 | ... | ... | ... | ... | 1491 | 558 | 606 |
| December ... | 1257 | ... | ... | ... | ... | 1767 | 1031 | 687 |
| Dominating winds for normal year | 9802 | ... | 7171 | ... | ... | 6421 | ... | 1840 |

It is of interest to note how the balance of power changes from month to month, while the peculiar characteristics of each month are also portrayed. In order to determine the final resultant power for each month, it is necessary to



resort to complicated mathematical calculations or geometrical construction in accordance with the principle of the parallelogram of forces; the latter method, which for convenience I have adopted, is with the exertion of care of sufficient accuracy for the present purpose, and it needs no detailed explanation. The yearly normal has been obtained in a similar manner, and the results are illustrated in Diagram C. (*Plate* II.)

It will be noted that from November to March, the winds blow persistently from the sea and during May to September in an almost opposite direction; April and October are peculiar to themselves, and of a neutral character. (In this and the following wind diagrams the arrows point with the wind). The yearly resultant or normal drift is interesting as regards direction and extent, it is in accord with the meteorologist's contention as regards the general ingress of the lower atmospheric layers from the pole to the equator, but it is contrary to a popular idea which is based upon the importance of prevailing winds (with us from the north-east).

The yearly resultant coincides to within a couple of degrees with the local magnetic deviation, and its relationship to the coastline might be noted. The seasonal changes already referred to are most apparent from Diagram D., (*Plate* III); this is founded upon the monthly normal winds from each point as recorded in Table VI., the arrow on the cardinals being proportionate to the mileage. The intervening areas have been coloured simply to assist the eye and are not otherwise representative. The central figure represents the normal year's winds, and has been divided into two sections—red and green—by a line along the direction of the average atmospheric drift already described, the marginal figures which represent the different months as named, have also been divided by lines parallel to the yearly drift.

From this it will be seen that the "reds" contain all winds blowing across the drift direction from west and north, while the "greens" contain those crossing from east and south. The individual months might now be considered—April and October show each about an equal quantity of red and green and have three primary winds—west, north-east, and south; in all these points the two months resemble the year, and have been placed on the dividing line—the central zone. From November to March the winds blow from north-east, east, and south, with a maximum of energy about January (midsummer); from May to September the blow is mainly from the west, with a maximum intensity about July (midwinter). It will be seen that the summer and winter are of *equal duration* (five months each) and they carry about the same mileage of wind.

Table VIII.—Showing the resultant wind-directions for each month and extent in miles (Normals).

| Month. | Direction. East | Miles. | Seasons. |
|---|---|---|---|
| October ... | N. 307·50 | 390 | AUTUMN |
| November | „ 284·00 | 2100 | SUMMER |
| December | „ 281·00 | 2900 | |
| January ... | „ 281·00 | 3050 | |
| February | „ 281·75 | 2780 | |
| March ... | „ 291·25 | 2185 | |
| April ... | „ 30·50 | 875 | SPRING |
| May ... | „ 67·75 | 2325 | WINTER |
| June ... | „ 86·25 | 3760 | |
| July ... | „ 79·50 | 3825 | |
| August ... | „ 77·75 | 2735 | |
| September | „ 84·50 | 1325 | |
| Resultant | „ 11·75 | 6700 | YEAR |

Having ascertained the *normal* features of the atmospheric movement for each month and for the year, it became necessary to find out to what extent individual years have differed from the mean. The object hereof was to discover whether *periodic* fluctuations do exist, and if so, to compare these with the gradual yearly increase and decrease in the abundance of fish—the assumed connection between



the two being as stated through the medium of the coastal currents. It was intended to single out such periods as would reasonably cover certain important spawning seasons, and the months involved were traced back through the twenty-four years under review. This comparison led to very interesting data meteorologically, and might with advantage be followed up by those concerned, but it would occasionally happen that within the same year one species of fish had a beneficial season while others met with reverses, and I found it desirable for the present to take all the seasons, *i.e.*, the year as a whole, and compare it with the total catch of mixed fish. From the monthly wind-mileage from the different compass points I have determined the atmospheric drift—the resultants—for each year since 1884, and find them to differ considerably from one another as regards direction and force. These yearly resultants have been set out in Diagram E, (*Plate* IV), and form an interesting study. In comparison with their average—the yearly normal—they show individually considerable differences, yet with one or two exceptions they all point north with an easterly or westerly tendency as the case may be.

It is well known that persistent winds have an all important influence upon the surface currents of the ocean; they become deviated from the normal flow, pushed aside one way or the other, accelerated in speed if the extra blow is with the currents, or temporarily brought to a standstill under certain other conditions. It is necessary therefore, when tracing the influence of the dominating or concentrated wind actions on the waters, to give regard to its two primary factors, *i.e.*, deviation from the normal and force or mileage.

A combination of these factors has been attained by disregarding them both individually and taking as their measure the nearest distance from the points of the arrows to the yearly normal or its continuation. It will be seen that the yearly wind resultants which coincide with the direction of the normal, have no disturbing influence; everything remains normal, and the extent of the disturbance occasioned by others is proportionate to their deviations one way or the other from the average mean. The result of this comparison is recorded in Table IX., and illustrated in Diagram F (*Plate* V). The mean line of the diagram is the normal or average for all the years, and the deviations west and east are shown respectively above and below.

Table IX.—Showing the result of each year's wind-deviation (in miles) when compared with the normals.

| Year. | Deviation in Miles. | | Year. | Deviation in Miles. | |
|---|---|---|---|---|---|
| | West. | East. | | West. | East. |
| 1884 | 1425 | ... | 1896 | 600 | ... |
| 1885 | 1050 | ... | 1897 | 3225 | ... |
| 1886 | ... | 4275 | 1898 | 2050 | ... |
| 1887 | ... | 3000 | 1899 | 5500 | ... |
| 1888 | 825 | ... | 1900 | ... | 2200 |
| 1889 | 2850 | ... | 1901 | ... | 3075 |
| 1890 | ... | 6000 | 1902 | 5525 | ... |
| 1891 | ... | 75 | 1903 | 3275 | ... |
| 1892 | 1475 | ... | 1904 | 2775 | ... |
| 1893 | ... | 850 | 1905 | ... | 6800 |
| 1894 | ... | 1625 | 1906 | 4875 | ... |
| 1895 | ... | 5175 | | ... | ... |

From a meteorological point of view it would seem of interest that the first half of the curve, up to 1895, is nearly all *below* the average, while the remainder is nearly all above. This means that during the former period, the winds had a greater tendency off the shore than latterly.

The second period coincides with the great Australian droughts (1895–1903 and 1904), and it is evident that for the same reasons as the winds blow on to the coast in the summer and away from it during the winter, so does also in dry (hot) years, the whole atmospheric drift have an exaggerated westerly (inland) tendency. This as will be seen afterwards, has a direct bearing upon the fisheries.



The separation of the period into two halves of very different character, suggests also the existence of an extended cycle or wave of which the twenty-four years under review form but a portion. The deviation in the yearly winds are seen to fluctuate within periods of a few years; distinct depressions in the curve (easterly deviation) occurred in 1895-6, in 1900-1, and in 1905. The intervening maxima (westerly deviation) occurred in 1897-99, in 1902, and in 1906. Here we have a direct measure of the disturbing influence of each year's winds upon the normal ocean currents touching the east coast of Australia, more particularly of New South Wales, and its application is very interesting. (Diagram G).

From certain ocean charts it will be seen that in the central Pacific, about 8 to 10 degrees south, there is a surface current flowing parallel to the Equator in a westerly direction. On approaching the archipelago fronting the south-east coast of Asia a main, arm of the current is directed south-westerly; it passes the Fiji and Norfolk Islands and is deflected still more southerly on meeting the Australian continent about the latitude of Moreton Bay; from here it follows the coast of New South Wales and Tasmania, where on meeting an easterly current from the Australian Bight, it turns east and north-east to the coasts of New Zealand.

From continued temperature observations I have had taken on board fast going steamers running between Sydney and New Zealand ports, it appears that the centre of the warm current is normally situated somewhere within 100 to 150 miles off the New South Wales coastline in the latitude of Sydney; its western border brushes along the headlands and is known to coasting crafts and line fishermen. Having its origin in conditions prevailing elsewhere, this current would during calm weather assert itself in its


**Diagram G.**

Showing normal current system in the Tasman Sea.

(After an American Chart.)



normal aspect; it would continue southwards along the New South Wales coast and have maximum speed at a certain distance from the shore. But the coastal winds interfere in this arrangement and temporarily push the current on to the coast or away from it. In the latter case, during stormy blows from west etc., the main current is not only itself carried seaward, but temporarily the surface waters from the coast follow in the same direction. The direct influence of the winds upon the fate of floating fish eggs is very apparent.

(1) When normal conditions prevail, the eggs follow the coast line and drift towards inlets situated to the south from the place of spawning.

(2) When pressed harder on to the coast through excessive easterly winds, the eggs will at any rate remain very close inshore and benefit these waters.

(3) When the winds blow excessively away from the coast, the eggs follow the waters, and whatever else may happen to them, they are lost to the coast that should have benefited by their numbers.

These reasonable contentions are amply demonstrated by comparison of the fish and wind curves already referred to, and reference may be made to Diagram H (*Plate* VI). The original curves are here represented in dotted lines A, C, E, and in order to form a better idea as to their main characteristics a "smoothed" curve (based upon three-yearly averages) has been introduced (B and D). Also it should be observed that the fish curve has been set back four years, so that the actual catch at any particular period may be directly compared with the wind conditions prevailing at the time the bulk of the catch was hatched out. It will be seen that the adverse winds (under the line or easterly deviation) that prevailed in 1894 and 1895 were followed by poor catches in 1898 and 1899; during 1897, 1898 and 1899 the winds were very favourable, and four years after the best fishing was enjoyed. The winds again became very "unfriendly" in 1900 and 1901, which was followed by great scarcity of fish in 1904 and 1905. In 1902 the winds suddenly changed for the better, and it will be seen how the abundance of fish increased from the greatest scarcity in 1905 to above the average in 1906. (See curve E which represents about 90% of the total catch). In the very close and detailed correspondence that is seen to exist between the dominating wind for any particular year and the abundance of fish four years hence, it is necessary to recognise a striking demonstration of *cause* and *effect*. The possibility of coincidence is not only fully excluded, but it is seen also that while the curves correspond with one another in the present comparison, they do not fit in if compared in any other way. It is unfortunate that the fish returns are unreliable prior to 1897, but from the records available, it is certain that fish were more plentiful in 1896 than in 1897, and this evidence, though general, is of strong corroborative value as supplementing the more direct evidence for the following ten years.

In this paper it has first of all been demonstrated that the abundance of fish on this coast is fluctuating in a manner that cannot fully be ascribed to the action of man; over-fishing alone is not a sufficient explanation. Secondly it has been demonstrated that the yearly dominating wind-direction is also fluctuating, some years it tends from the sea to this coast, and at other times from the coast seawards; and thirdly we find that the "ups" and "downs" in the abundance of fish correspond with the "ins" and "outs" of the dominating wind directions four years previously. Apart from the scientific aspect of this discovery, it has also great practical consequences and a direct bearing upon legislation as to closures, etc. Furthermore it will be seen that if this evil effect of the adverse winds could be overcome by retaining the fish-eggs instead of letting them drift away, much good would be attained. Fish culture is the only means to this end, and has in many countries demonstrated its beneficial influences.

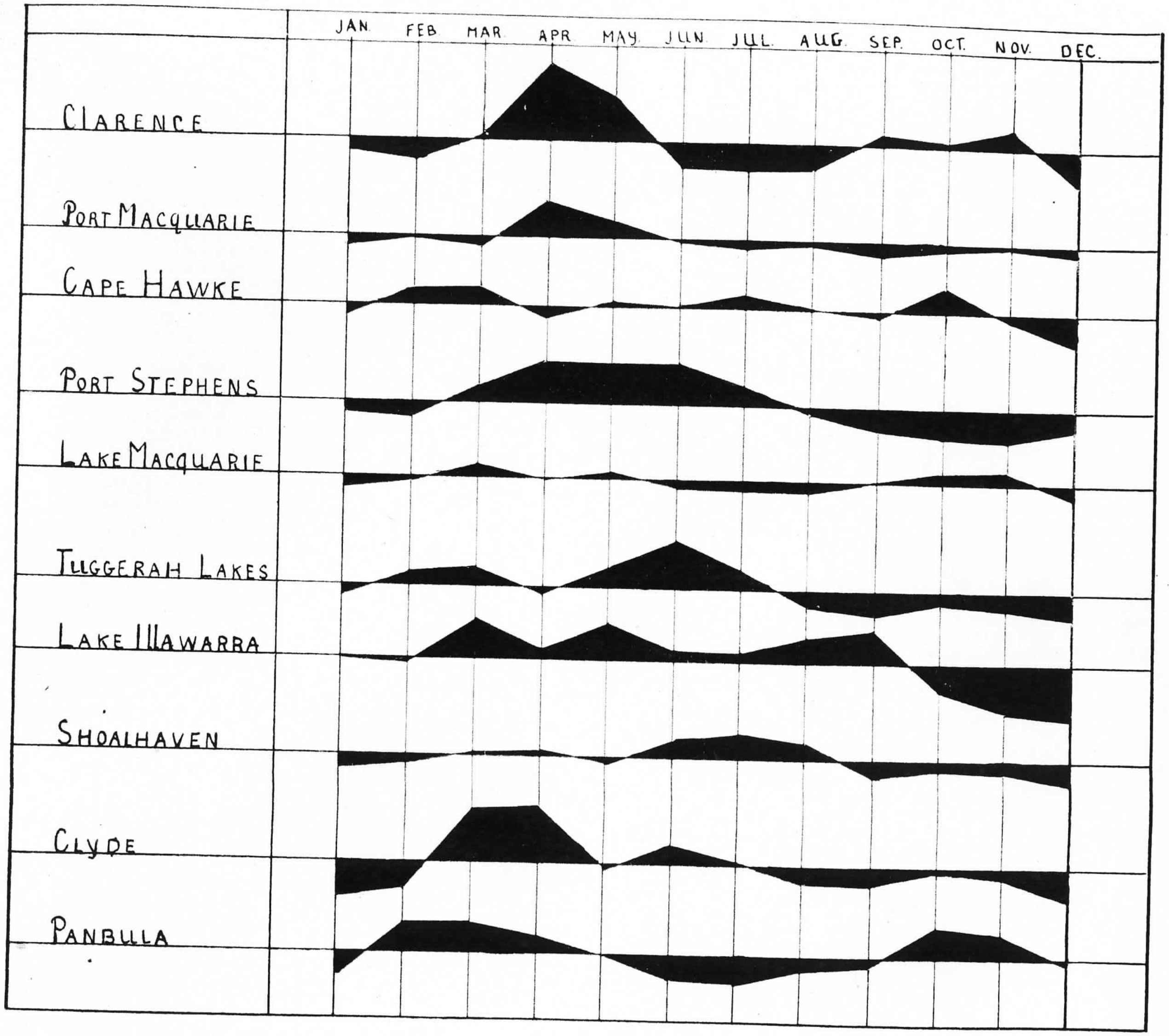


A final phase of the relation between winds and the fish is that as this year's wind conditions determine what like the fisheries shall be four years hence, viz., in 1911, and last year's winds dealt with the eggs that should make up the catches in 1910, we have in the wind records suitable materials to form a "forecast" for each of the next four years to come.

On reference to Diagram H it will be seen that as the winds in 1902, 1903, and 1904 were favourable, so ought also the fishing to be in 1906 (which happened) and in 1907 and 1908. It is not desired, however, that much prominence shall for the present be given to this apparently very important aspect of the matter. There are too great interests involved, and while the experience of time adds value to the existing evidence, those most directly concerned had better continue as formerly, by taking things by chance. In the meanwhile it will be interesting to watch future developments, and I feel confident that by each succeeding year we approach a stage of greater certainty, when fisheries investigations on a scientific basis will also in Australia become the recognised means for determining important problems, and the general guide to advancement and progress.

## Diagram A.

Showing relative abundance of Fish each Month.



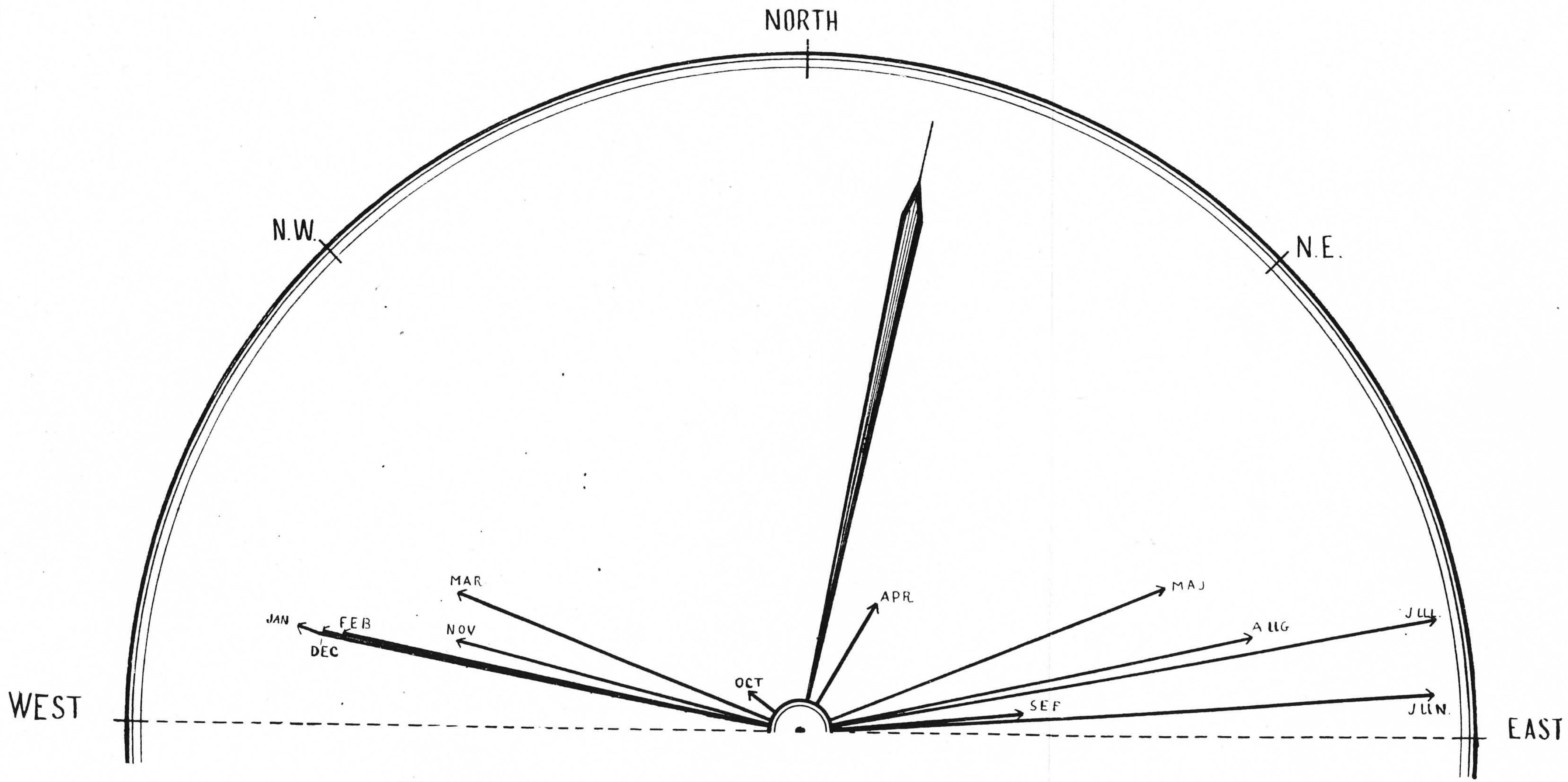
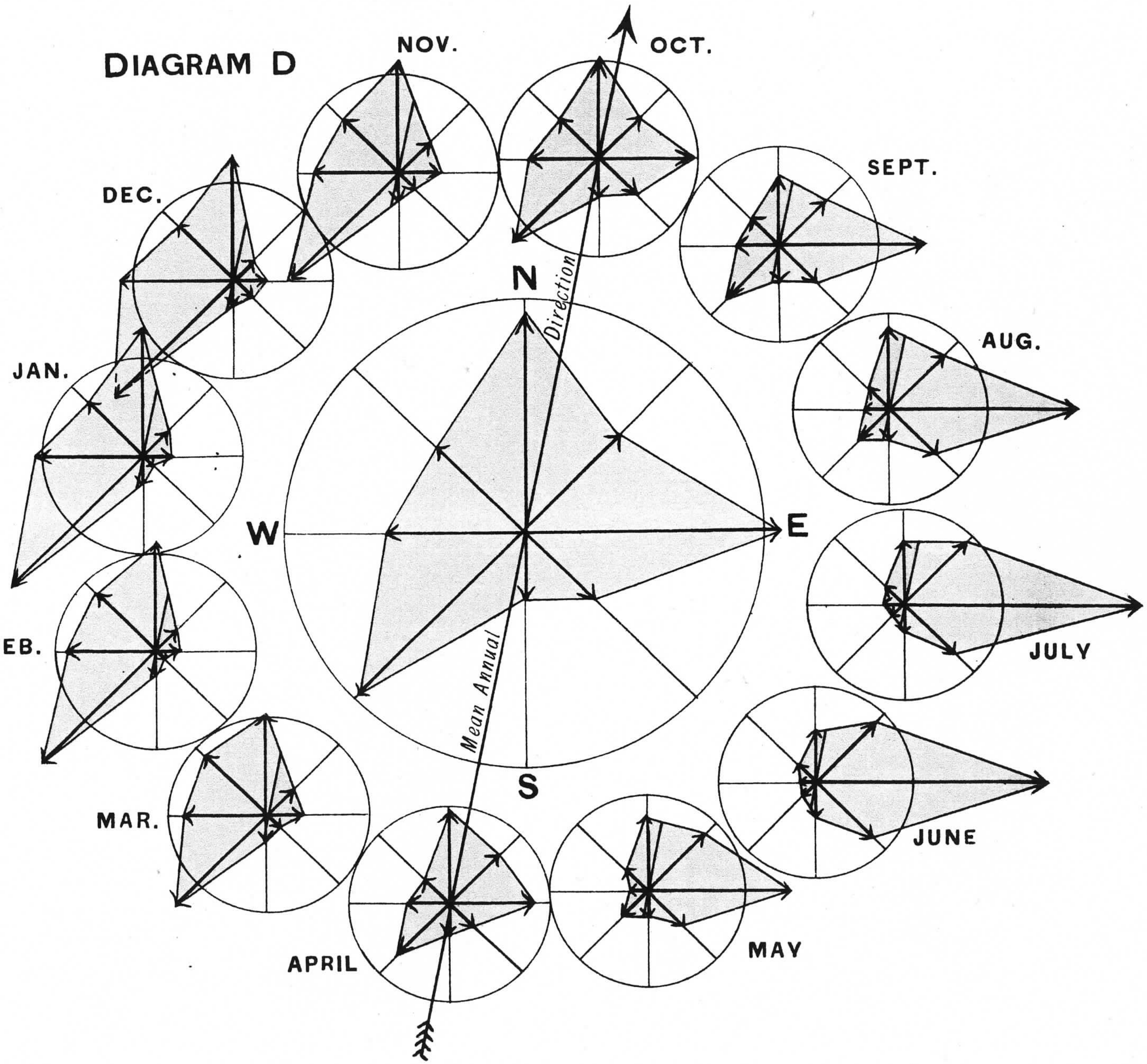



**Diagram C.**—Showing the resultant winds each month, and for the year (Normals).




SYDNEY: WILLIAM APPLEGATE GULLICK, GOVERNMENT PRINTER.—1907.

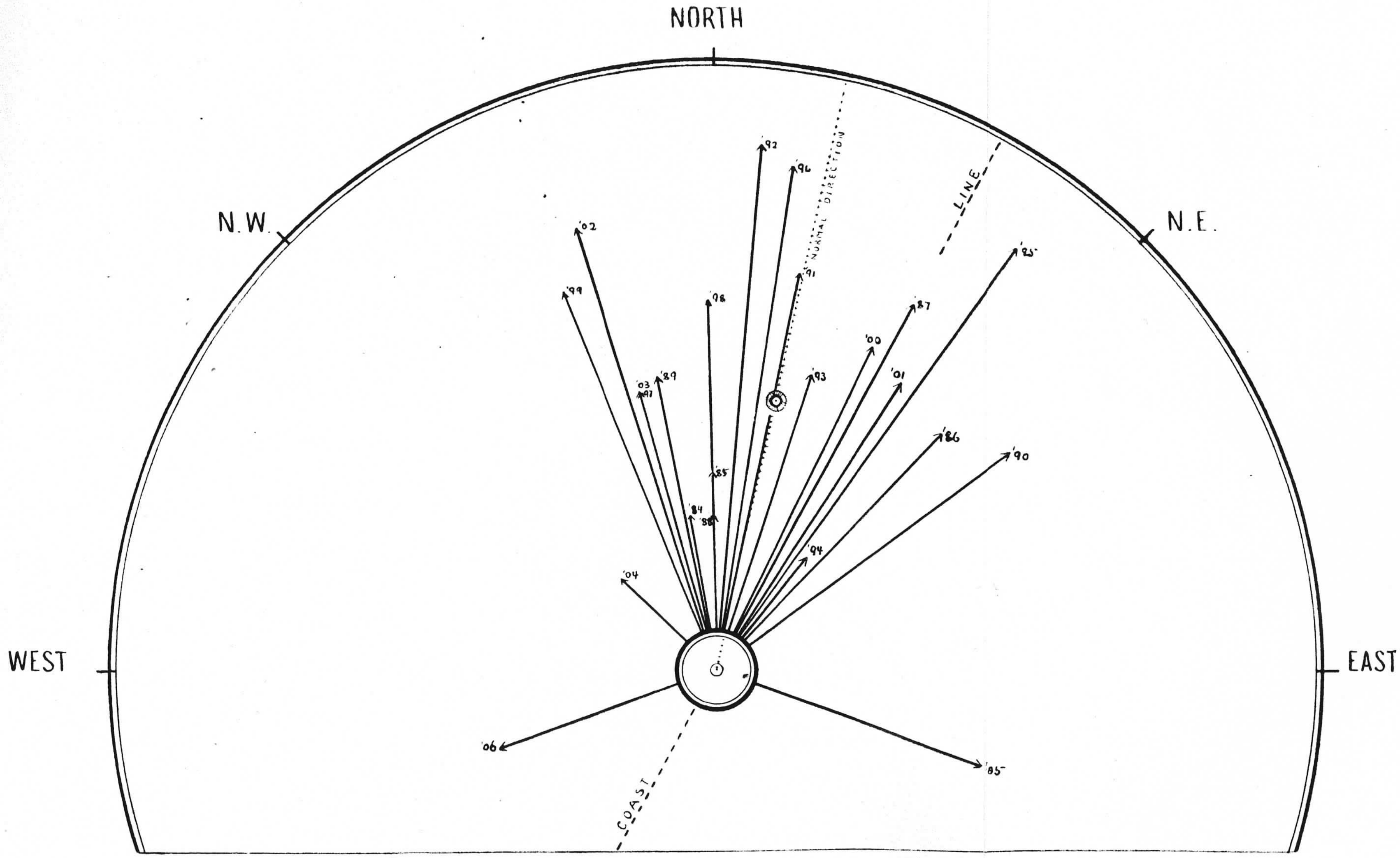



**Diagram E.**—Showing the resultant wind for each year (1884 – 1906).

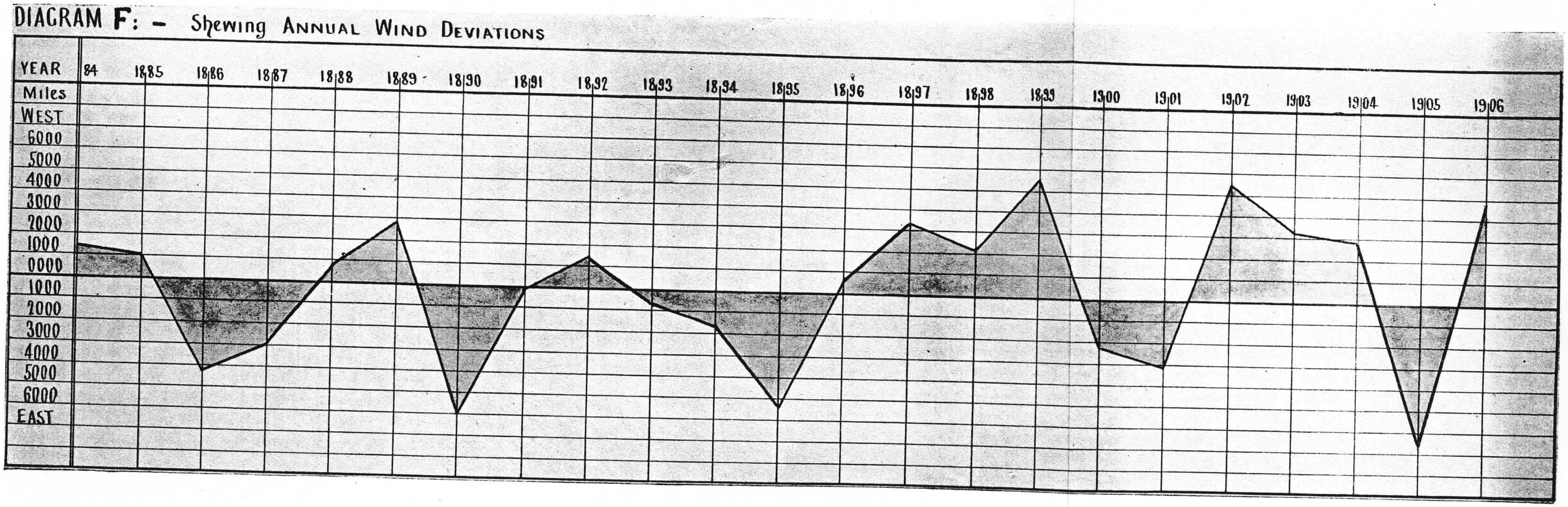


DIAGRAM F: - Shewing Annual Wind Deviations
YEAR
84
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
Miles
WEST
6000
5000
4000
3000
2000
1000
0000
1000
2000
3000
4000
5000
6000
EAST

DIAGRAM H:- Shewing Correspondence between Annual Wind Deviations and Fluctuations in the Abundance of Fish.