NEWS AND VIEWS

Hydromechanics of Fish Migration

IN a note in this issue of *Nature* (page 48) Weihs discusses some aspects of the energetics of fish locomotion and concludes, on theoretical grounds, that it would be advantageous to swimming fish, in terms of energy of movement as a proportion of a given total energy store, if their speed through the water was maintained at about one fish length per second. Independent experimental evidence, not referred to by Weihs, suggests that this swimming speed may indeed have some physiological significance: for it is at prolonged swimming speeds above that of one fish length per second—where it has been shown in the coalfish *Gadus virens*—that the diameter of the white (anaerobic) muscle fibres starts to increase.

Studies on schooling or shoaling of fishes have suggested that there is an upper limit to the searching speed of predators and that they could achieve this digit at speeds less than the cruising speed of three lengths per second established by experimental observations. The underwater films of tuna from the RV Townsend Cronwell give the impression of rather slow and idle swimming between meals.

Weihs's conclusions suggest that the extent of a migratory circuit could depend on the size of the fish. Furthermore, as the migratory movements themselves—for example, feeding area to wintering area, and wintering area to spawning area—are seasonal, the distances between the area could be similarly limited. The figures in the table below show the distances that various fish could cover each day when swimming at 1 length s^{-1}.

It is known that herring in the North Sea may migrate about 600–800 miles yr^{-1} on a straight course and that the Arcto-Norwegian cod may cover 1,500 miles yr^{-1}. Hence the least period spent on migration is 50–70 days for the herring and 30–60 days for the cod (or one sixth of the year). A straight course migration implies some orientation to a current, which is unlikely. On more devious courses the fishes may spend a much greater part of their lives in migration. The migratory range could perhaps be extended by behavioural or physiological adaptations; for example, the distance travelled could be substantially increased if the direction of migration was downstream in the direction of the main ocean currents, rather than against them. And in areas where tidal currents are significant, economies could be achieved, and the range of migration extended, if the fish joined those tides which would carry it in the direction of migration.

Length (cm)	Species	Speed in knots	Distance covered in 24 h (nautical miles)
10	Sprat	0.2	4.8
25	Herring	0.5	12.0
50	Small cod	1.0	24.0
100	Big cod	2.0	48.0
150	Tuna	3.0	72.0

A comparison between a cod and a salmon suggests a line of physiological adaptation. Both fish, when sexually mature, are of similar size, say 70 cm. Both species undertake long spawning migrations; mature Arcto-Norwegian cod move from Bear Island to the west Fjord, from 74° N to 68° N, and those salmon which spawn in the headwaters of the Fraser River, British Columbia, move from 49° N to 55° N, and then after having returned to their coastal waters from the high seas. But although cod in the sea might have to swim against a 1 knot (50 cm^{-1}) current, the salmon in freshwater must swim against a very much faster flow and one suspects that a cod-like fish would not undertake the migration carried out by a salmon of similar size unless it was designed somewhat differently. It is well known that the muscle systems of the two species are very different.

The energy devoted to swimming is equal to that devoted to maintenance. Growth is proportional to converted food less maintenance. Hence it might be expected that the more migratory fish grow less than the less migratory ones. Plaice migrate about half the distance of herring and are much larger. But such comparisons cannot be extended very far.

Weihs's argument draws attention to the fact that very little is known about the locomotory behaviour or swimming performance of fish on migration: the information from tagging returns is very limited. Recent advances in sonar techniques, both in Nortn America and the United Kingdom, however, provide the means of tracking individual fish in lakes, rivers and the open sea for periods up to several days. Data collected from such studies should go some way to fill in some of the gaps in knowledge.

From a Correspondent

Magnetic Fields Adrift

THAT versatile genius, Edmond Halley, astronomer, geophysicist, navigator, and surveyor, made the first extensive geomagnetic survey and drew up the first chart of magnetic declination, covering much of the Atlantic Ocean. He noticed that the secular variation of the field, which had already been detected for London by Gellibrand, a Gresham Professor of Astronomy, behaved as if the Earth's field were rotating in a westerly direction relative to the surface of the Earth. Halley then went on to propose a model of the Earth which is in some ways remarkably like the model now accepted of a core surrounded by a mantle.

There the matter rested, attracting little attention until, some two and a half centuries later, Sir Edward Bullard re-examined the secular variation in Africa. He and his colleagues showed that the secular variation could be accounted for by electrical currents flowing in closed loops near the surface of the liquid, electrically-conducting core of the Earth, the whole system drifting westwards relative to the surface of the Earth. Apart from its account of the secular variation, this conclusion proved to be of great importance because it led Bullard himself, as well as others, to examine the possibility that the main field of the Earth might be generated by electrical currents maintained in the core by some sort of dynamo action.

Malin and Saunders (see page 25 of this issue) have now re-examined the secular variation to see whether, as