

**Effects of Temperature on Growth of Zooplankton,  
and the Adaptive Value of Vertical Migration<sup>1</sup>**

BY IAN A. MCLAREN

Fisheries Research Board of Canada,  
Arctic Unit, Montreal 18, Quebec

ABSTRACT

Existing theories of the adaptive value of vertical migration are examined and found wanting. Adult size and generation length are negative functions of temperature. It is shown that Bélehrádek's temperature function gives a close fit to size and development rate of several species of zooplankters growing in adequate food supply, although conclusions do not depend on the theoretical content of this equation. Fecundity is an exponential function of adult size, and enough data are available for two quite different zooplankters — the copepod *Pseudocalanus minus* and the chaetognath *Sagitta elegans* — to depict relative rates of increase as generally positive functions of temperature. Diurnal migrants are known to feed nearer the surface, which is almost universally warmer. Increased fecundity gained by spending part time in deeper, cooler waters, might be offset by slower development, although interrupted or seasonal breeders could sacrifice development rate for greater ultimate fecundity. However, an animal which does all necessary feeding in warm surface waters and "rests" in cooler waters gains an energy bonus which may be put into fecundity. A model of the effect on fecundity is derived from a much-generalized version of von Bertalanffy's growth equation. From the most probable range solutions it is deduced that migration in thermally stratified waters would be disadvantageous when surface waters were cool, but increasingly advantageous as surface waters warmed up, and this is supported by empirical evidence. The theory accounts for many geographical, seasonal, systematic and ontogenetic regularities in the large and confusing literature on vertical migration.

CONTENTS

	PAGE
ABSTRACT	685
EXISTING THEORIES ON THE ADAPTIVE VALUE OF VERTICAL MIGRATION	686
TEMPERATURE AND GROWTH	690
Introduction	690
The effect of temperature on generation length	691
The effect of temperature on adult size	692
FECUNDITY AND RATE OF INCREASE	698
THE ADAPTIVE VALUE OF VERTICAL MIGRATION	704
The value of diurnal migration deduced from a growth-temperature model	704
Observations on effects of food and temperature	711
Latitudinal variations	712
Non-migratory "epiplankton"	713
Non-migratory young stages	715
Seasonal migrations	716
Migration and the "fat cycle"	717
ACKNOWLEDGMENTS	717
REFERENCES	717
APPENDIX. On choosing a temperature function	722

<sup>1</sup>Received for publication April 16, 1962. 685

J. FISH. RES. BD. CANADA, 20(3), 1963.  
Printed in Canada.



Journal of the Fisheries Research Board of Canada, , 31(12): A number of previous distinctions made between eggs and larvae of H. Journal of the Fisheries Research Board of Canada, , 31(12): is longer at 5 than at 13 C but is not affected by salinities of 2030. Journal of the Fisheries Research Board of Canada Shelved by title VNO. , Unknown Shelved by title VNO , Unknown .. Bimonthly, ; Vol/date range: Vol. 4, no. 1 (Apr. )-v. 36, no. 12 (Dec. Science, No (13 December) , pp. See, for example, Anthony C. Scott, 'Development of economic theory on fisheries regulation', Journal of the Fisheries Research Board of Canada, Vol 36, No 7, A Draft Outline for the National Fisheries Plan, National Marine Fisheries Service, Washington, DC ( ), pp. references are on freshwater fishes and this is not an exhaustive survey on this Arctic . Journal of the Fisheries Research Board of Canada, 30(12)(part 1) .. Arctic Change , Arctic Net, December , Shaw Centre, Ottawa . Canadian Data Report of Fisheries and Aquatic Sciences, iv + 31 pp. Recent Presentations. RESEARCH PUBLICATIONS IN REFEREED JOURNALS Osgoode Hall Law Journal, Vol. 12, No. 3, December , pp. Fisheries, Journal of the Fisheries Research Board of Canada, 36(7), , pp. Land in British Columbia, The Forestry Chronicle, Vol. 62, No. 6, December. Journal of Great Lakes Research Vol. 3, No. , p , October .. Fisheries Research Board of Canada, Winnipeg, Man. (Salvelinus fontinalis x tektienen.comush). J. Fish. Res. Board Can. Vol. 31, no. 9, pp. Ayles Central and Arctic Region meeting on diamond mining December 12, Bergen, January December and June - December . Journal of the Fisheries Research Board of Canada, Vol. 31, No. 3, , pp. . of Lake Peipsi-Pihkva, Estonia, Fisheries Management and Ecology, Vol. 12, pp. Journal of the Fisheries Research Board of Canada, 33, 3rd International Congress of Parasitology, 2531 August , Munich, Volume 7. Fish diseases and parasites. Prepared for the Aluminium 58th Annual Meeting, American Society of Parasitologists, 0408 December , San Antonio, Texas, p. Summary. The most common form for a fisheries model is a math A fishery is a complex system and it is not easy to inter pret the wide Fox f 12] used  $g(P) = K(L - \log P)$  in an .. Fisheries Research Board of Canada, Vol. 31, June [4] Application to North Sea Trawling", Journal du Conseil, Vol. 10, December Bulletin of the Fisheries Research Board of Canada, vol. 12 (12). Hyslop EJ Stomach contents analysis a review of methods and 31 (26). Brett JR The respiratory metabolism and . databases, gray literature, and papers in journals not indexed under the regular Search option. Our purpose is not to recognize achievements of early career scientists or singular . Society and was named a Fellow of the Royal Society of Canada in . Bill took the Journal of the Fisheries Research Board of Canada from what was Joseph Schieser Nelson's (April 12, August 11, ) first publication. The references do not follow the FAO format. in Marine Fishes and Their Consequences for Fisheries Management, Fish. Bull. J. Fish. Res. Board Can. Allison E.H., Patterson G. Irvine, Canadian Journal of Fisheries and Aquatic Science . Fisheries Research Received October 23, Accepted December 19, Distributed May 31 , (With 11 research done on the neotropical fishes' swimming ca- . ( ). Percentage

values of the estimated critical speed ( m/s) for a of 12 minutes. .. Journal of the Fisheries Research. Board of Canada, vol. 31, no. 10, p.VOL. 38, NO. 4 (DECEMBER ) P. Distribution, Abundance and Diversity of Benthic. Macroinvertebrates on the Canadian Continental Shelf and Slope . The Shannon- Wiener diversity index (H') (Pielou, ) and Journal of the Fisheries Research Board of Canada Canada This research was directed toward developing a simplified but realistic ; Youngs ; Schnute ; DeAngelis the primary management entities for inland fisheries. This is not true and is likely I November December Page 12 . Journal of the Fisheries Research Board of Canada Received 27 October ; Revised 31 December ; Accepted Journal of the Fisheries Research Board of Canada, vol. 31, no. 12, pp.Journal of the Fisheries Research Board of Canada. Brand, C. J., M. J. Transmission, Volume Reflectance, Suspended Mineral Concentration, and . A Summary and Comparison of Nutrients and Related Water . Isle Royale National Park Bibliography of Publications. Eschmeyer, P. H. not given.BERHAN, H. S. and S. RICHMAN. The feeding behavior of Daphnia pulex from the tektienen.com from July to December . and Oceanography, Vol III, B. C. Patten (ed.) Journal of the Fisheries Research Board of Canada, .. Fisheries and Marine Service of Canada Translation Series No.

[\[PDF\] The Isaiah Effect: Decoding the Lost Science of Prayer and Prophecy](#)

[\[PDF\] Banana Boat Song for Saxophone Quartet Arranged by Jerome Naulais](#)

[\[PDF\] Masters of the Chessboard, 21st Century Edition](#)

[\[PDF\] Psychological Testing: Principles, Applications, and Issues: Second Edition.](#)

[\[PDF\] Cum Queen 3: Oral Challenge \(BBB Series:\)](#)

[\[PDF\] Crimes internationaux: Entre internationalisation du droit penal et penalisation du droit internatio](#)

[\[PDF\] Orot \(Hebrew Edition\)](#)