

relate to the Northern hemisphere, the dotted curves pertain to the Southern hemisphere. In Table I, we have given numerical values of θ_M and θ_{M^*} at some longitudes. It can be noted that

TABLE I

$\alpha_e = 40^\circ$			$\alpha_e = 80^\circ$		
λ^0	θ_M^0	$\theta_{M^*}^0$	λ^0	θ_M^0	$\theta_{M^*}^0$
0	62.92007	116.6652	0	85.1737	94.9865
45	59.17703	112.2483	45	79.1285	92.1337
90	57.0270	109.4838	90	74.6924	91.5340
135	56.3157	109.1483	135	73.9306	91.3635
180	59.5042	112.1550	180	79.6675	92.2540
225	66.1607	118.4004	225	86.5975	97.7513
270	73.8044	126.1906	270	88.7151	108.1319
315	69.8519	126.3337	315	88.5859	107.1669

M and M* are conjugate mirror points.

the mirror point has a strong dependence on the longitude. Also, $\theta_M + \theta_{M^*}$ is not equal to 180° , unlike the dipole case. The curves indicate that the distribution of θ_M with respect to the longitude has a similar pattern for all values of α_e .

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SEX-RATIO IN FISH POPULATIONS AS A FUNCTION OF SEXUAL DIFFERENCE IN GROWTH RATE

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DURING a study of the biology of some fishes from the inland waters of India (Qayyum and Qasim, 1964), the sex-ratios in the population of various species were determined by taking regular monthly samples over a period of one year or more. It then appeared that in some species like *Ophicephalus punctatus*, males were in the majority, whereas in others, *Barbus stigma* and *Callichrous bimaculatus*, females outnumbered the males. Such differences in the sex-ratio remained unexplained until the growth rate of the two sexes in each species was examined.

Table I gives the total length frequencies of all the species under investigation. It can be seen from the table that in *O. punctatus*, the males attain a size larger than the females. This was further confirmed by a study of the growth rate of the fish from opercular bones and scales (Qasim and Bhatt, 1966). In *B. stigma* and *C. bimaculatus*, on the other hand, the females grow bigger than the males. Since no reliable method of age determination in these two species could be found out, this inference was drawn by a study of the length frequency distribution alone. In *B. stigma* which attains a maximum size of 13.0 cm., fishes larger than 10.0 cm. were all females and the same was true in *C. bimaculatus* where all fishes larger than 26.0 cm. were females (Table I).

It therefore seems that the preponderance of one sex in the population is because of the sexual difference in growth rate. Faster growth

TABLE I

Length frequencies and sex-ratios in three different freshwater fish populations of India

Species	<i>Ophicephalus punctatus</i>		<i>Barbus stigma</i>		<i>Callichrous bimaculatus</i>	
	Males	Females	Males	Females	Males	Females
Length groups cm.						
3.0	..	..	12	19	..	..
4.0	..	..	31	28	..	..
5.0	33	29	12	19	..	..
6.0	28	29	28	25	..	..
7.0	33	26	30	33	2	1
8.0	38	23	96	68	5	1
9.0	74	74	34	118	16	12
10.0	75	59	7	47	24	33
11.0	58	49	..	21	35	56
12.0	53	44	..	5	31	49
13.0	54	57	..	1	24	46
14.0	53	59	..	..	29	50
15.0	55	57	..	..	41	43
16.0	30	42	..	..	27	37
17.0	32	25	..	..	26	30
18.0	19	17	..	..	19	24
19.0	18	20	..	..	16	17
20.0	23	6	..	..	13	21
21.0	17	6	..	..	12	17
22.0	11	9	..	..	11	24
23.0	21	6	..	..	7	16
24.0	13	1	..	..	5	14
25.0	14	..	..	..	2	10
26.0	10	..	..	..	4	12
27.0	5	..	..	..	..	10
28.0	2	..	..	..	..	12
29.0	3	..	..	..	..	..
Total ..	772	638	250	384	349	535
Sex ratio	1 : 0.82		1 : 1.5		1 : 1.5	

probably leads to increasingly less effect from predation and this may influence the sex-ratio in favour of the sex growing faster. It may further affect the sex-ratio through other extrinsic factors beside predation, for the existence of a size hierarchy in the population will favour the large-sized individuals in both intra and interspecific competition for food and space. In other words, it seems that survival is a function of length.

To test this hypothesis the sex-ratios and the growth of each sex of some of the marine and freshwater fishes for which data are available were compared (Table II). The basis of comparison has been to include the concept of sex-ratio in the picture outlined by Beverton and Holt (1959). The various parameters worked

maximum asymptotic length and K is a constant.

The other parameters in Table II are:

M = coefficient of mortality

$T_{max.}$ = the maximum recorded age of the species

L_m = the average length at maturity

L_m/L_∞ = the ratio between the size at first maturity and asymptotic length.

It will be seen from Table II that in each species L_∞ shows definite trends and points directly towards the preponderance of sexual numbers in the population. The only species which seems to fall out from this generalisation is the bullhead, *Cottus gobio* where perhaps the L_∞ between the two sexes does not differ significantly to affect the sex-ratio and presumably for this reason, in the two samples

TABLE II

Data on growth, sex-ratio and other related parameters of some marine and freshwater fish populations

Species	Common name	Locality	Author	Sex	L_∞ (cm.)	K	M	$T_{max.}$ (sample)	L_m (cm.)	L_m/L_∞	Sex-ratio m : f
<i>Pleuronectes platessa</i>	Plaice	North Sea	Beverton and Holt (1959)	m	45	0.15	0.22	13	25	0.56	1 : 1.115*
				f	70	0.08	0.12	22	28	0.40	
<i>Callionymus lyra</i>	Dragonet	English Channel	Chang (1951)	m	25.0	0.43	0.96	4	17.4	0.70	1 : 0.58
				f	17.5	0.55	0.86	6	..	..
<i>Cottus gobio</i>	Bullhead	Windermere R. Brathay	Smyly (1957)	m	7.2	0.7	1.1	4	4.6	0.64	1 : 0.88
				f	7.3	0.4	0.9	6	4.2	0.58	
				m	6.5	0.9	0.9	4	≈ 5	≈ 0.77	
				f	6.5	0.5	0.8	6	≈ 5	≈ 0.77	
<i>Blennius pholis</i>	Blenny	Welsh Coast	Qasim (1957a)	m	17.2	0.28	1.15	6	8	0.47	1 : 1.07
				f	16.8	0.33	0.96	6	8	0.47	
<i>Gadus minutus</i>	Poorcod	English Channel	Menon (1950)	m	20	0.42	1.1	5	11	0.55	1 : 1.80
				f	24	0.40	0.9	5	13	0.54	
<i>Centronotus gunnellus</i>	Butterfish	Welsh Coast	Qasim (1957b)	m	18.9	0.35	1.52	6	9	0.48	1 : 1.19
				f	18.4	0.42	1.91	6	9	0.49	
<i>Ophicephalus punctatus</i>	Murrel	Aligarh ponds, India	Qasim and Bhatt (1966)	m	32.3	0.20	0.75	7	11	0.33	1 : 0.82
				f	21.2	0.45	1.24	7	11	0.51	
<i>Oncorhynchus keta</i>	Chum-salmon	Columbia R., Canada	Marr (1943)	m	120	0.27	(3.0)	5	81	0.68	1 : 0.84
				f	105	0.30			75	0.72	
				m	106	0.45	(1.2)	5	75	0.72	1 : 0.96
				f	102	0.39			70	0.69	
		4-year Spawners									
		3-year Spawners									

* Values based on data given by Graham (1956).

out by these authors have been kept the same and in some species where it was found necessary, these parameters were calculated according to the methods suggested by these authors (see Beverton and Holt, 1956, 1957 and 1959). These parameters are based on the well-discussed exponential equation of von Bertalanffy which in its simplest form reads:

$$l_t = L_\infty (1 - e^{-kt})$$

where l_t is the length at age t , L_∞ is the

examined by Smyly (1957), the sex-ratio seems to work either way. In some of the other species indicated in Table II, females are larger and more abundant in the population. In *O. punctatus* and *O. keta*, males are more abundant and they grow significantly larger also.

As a general rule it might be expected that a greater increase in size is directly associated with a greater longevity of one sex and consequently the parameter $T_{max.}$ would affect the

sex-ratio of the population more directly than L_{∞} . However, a close examination of Table II will reveal that this is not always true as when T_{max} in the two sexes is the same, one would expect both sexes to occur in fairly equal numbers in the population. On the contrary, in those species (*B. pholis* and *C. gunnellus*) where T_{max} in both sexes has been found to be the same, there is a clear difference in their sex-ratio. This seems mainly associated with the sexual difference in L_{∞} , and indeed in those species (*B. pholis* and *C. gunnellus*) where L_{∞} does not differ or only differs slightly, both sexes occur in fairly equal numbers (Table II). The very interesting example is that of *C. lyra* where males are short-lived yet larger and more abundant in the population.

However, in most cases a greater increase in length of one sex is associated with a greater longevity, i.e., a higher T_{max} (see Table I, Beverton and Holt, 1959). This may in itself be due to the influence of intrinsic factors upon the individuals of the population. Faster growing sex may be that which is better adapted physiologically and thus the intrinsic factors will also affect the sex-ratio in favour of the sex growing faster.

That the survival is a function of length is further confirmed in each species by the inverse relationship traced by Beverton and Holt (1959) between L_{∞} and K and a direct association between M and K . Since K is closely related to metabolic rate of the fish (see Beverton and Holt, 1957 and 1959), it is evident that a higher K of any one sex will lead to an increase in M . In other words, M will be less when L_{∞} is greater. The only exceptions to this rule seem to be the dragonet, *C. lyra* and the three-year spawners of the chum salmon, *O. keta* (Table II). In the former case the males have a lower K and a higher M and in the latter a higher K is associated with a higher L_{∞} in males. The case of *C. lyra* may be considered as exceptional and extreme because the life of the males comes to an abrupt end soon after spawning (Chang, 1951), and for this reason M is higher. No explanation could however be found for the

association of a higher K with a higher L_{∞} in males of the three-year spawners of *O. keta*.

Another interesting feature which emerges from the analysis of these data is the relationship between L_m/L_{∞} and M . Generally a higher L_m/L_{∞} is associated with a lower L_{∞} and a higher M , and the statement of Beverton and Holt (1959) that short-lived species are those which have a higher L_m/L_{∞} , seems to be true among the two sexes of the same species also. Probably a greater mortality of one sex, be it male or female, is because of increased metabolic strain of reproduction for they mature at a size which is relatively larger in relation to their L_{∞} . This would also account for the sexual difference in the asymptotic length.

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