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Production efficiency of two demersal finfishes in the trawling grounds off Veraval

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ABSTRACT

The feeding rate of *Nemipterus japonicus* in the trawling grounds off Veraval decreased with advancing age from 5.8% body weight/day (age: 0.1-0.5 year) to 4.0% bw/d (3.0-3.5 y) with an average of 4.7% bw/d. The production efficiency was 0.06. i.e. 6% of the consumed food was converted for growth. The feeding rate of *Saurida tumbil* also decreased with advancing age from 10.8% bw/d (age: 0.2-0.5y) to 7.8% bw/d (4.0-4.5 y) with an average of 9.1% bw/d. The production efficiency was 0.03. The annual food consumption of the exploited biomass (27131) of both the species was 60.923 t. The annual food consumption of the two species was almost equal to that of the total trawl landings at Veraval. indicating high predation mortality in the ecosystem.

Introduction

Food intake is the major factor controlling fish production. Estimates of food intake and growth are valuable in assessing basic biological information, ecological relationships, the extent of predation and production efficiency. Production efficiency represents the efficiency of food conversion to growth is the best source of ecological efficiency of fish stocks (Sainshury, 1988). Moreover, data on annual biomass consumption and production of each fishery group are prerequisites to understand the functioning of the trophic food web and the level of predation mortality (Mendoza, 1993), which are essential to adopt applied ecological approaches of fisheries management (Christensen and Pauly, 1993). There are several estimates of food consumption of temperate fish populations based on the amount of food in the stomach of fishes (for e.g.. Windell, 1978). Studies on food consumption of Indian marine fishes are mostly of qualitative nature and the available quantitative estimates do not provide information on the food consumption at population level. The growth studies are restricted to estimates of von Bertalanffy growth parameters for single species and there are only a few attempts so far to correlate food consumption and growth of fish populations (Devaraj. 1999 a,b,c). The present study is an attempt to estimate food consumption and production efficiency of two important demersal fishes, the threadfin bream, *Nemipterus japonicus* and the lizardfish *Saurida tumbil* in the trawling grounds off Veraval.

Materials and methods

Fresh specimens of *N.japonicus* (n=1318; length range: 50 to 310 mm) and *S.tumbil* (n=1245; length range: 70 to 555 mm) were collected during April 1989 - March 1991 from private trawlers operating off Veraval coast. The total length and weight were measured for all the individuals. The stomach of all the fishes was cut longitudinally and the stomach contents were collected in a petridish. The adhering digestive liquid from the body was removed with filter paper. The stomach contents, which were in reasonably undigested condition, were identified up to species/genus/group level, depending on the stage of digestion. The weight of individual/group of prey of same species was taken by using a balance of 0.1 mg accuracy. The food items which were digested completely in semi-liquid condition were passed through a filter paper and the particles retained by the filter paper were carefully scrapped and weighed. The total weight of the identified prey and the partially digested matter provided an estimate of the food consumed by the fishes in the sample. The average weight of food consumed, also called ration (R), was estimated as R= W/n, where W = total weight of food consumed by n number of fishes in the samples (Hastings and Dickie. 1972). The R is considered to represent the quantity of food consumed during an active period (Ivlev, 1955). Considering that each fish attains satiation at least once daily through active feeding, the R represents the daily food consumption (Winberg. 1956). The feeding rate (R/w; % body weight/day) was estimated by dividing the total weight of food in the sample by the sample weight of fish.

Based on length frequency method, Gopal and Vivekanandan (1991) estimated the growth of *N.japonicus* (1987-1990) and S. *tumbil* (1989-1991) off Veraval. The following von Bertalanffy growth equations suggested by these authors were used to determine the weight (g) at age (Wt):

N.japonicus: $Wt = 491 \, (1-{}_{e}{}^{\circ}-{}^{733<t+01167>})^{2} \, -{}^{749}$

S. *tumbil:* $Wt = 1982 \, (1 \, {}_{e}{}^{0577(\prime + 0038} >)^{2951}$

The growth rate (W/w; % body weight/day) of each age group was determined as W/w = (AW/day)/mid body weight.

Indices of food utilization for growth were derived from the following ratios suggested by Hastings and Dickie (1972):

C = RAt/W, and K = AW/RAt,

where, C = conversion factor, RAt = ration per unit time At. AW = growth increment during the same unit time and K = gross production efficiency.

Data on the landings of *N.japonicus* and *S. tumbil* and effort of the private trawlers at the Veraval fisheries harbour were collected twice a week during April 1989-March 1991. The data were weighed for monthly and annual values. The length data collected on each observation day were raised to the day's catch and these were further raised to get monthly and annual length composition in the landings. The annual average exploited number and biomass of the half-yearly age groups were estimated by employing the von Bertalanffy growth parameters. Food consumption by the exploited populations was estimated by using the data on the annual exploited biomass and the daily feeding rate. The composition of annual food consumption by the exploited populations was estimated by considering that the percentage composition of the food items, which were in identifiable condition, represented the entire stomach contents.

Results

N.japonicus

The daily food consumption (R) of *N.japonicus* increased with advancing age, from 0.96 g/fish/day (age: 0.1 to 0.5 year) to 15.34 g/fish/d (age: 3.0 to 3.5 years) (Table 1). In other words, the R increased with the increasing weight (W) of the fish with the following linear relationship (Fig. 1): logK =-1.072+ 0.878 log W;r = 0.999.

where w = mid body weight (g) of the fish in successive half-yearly age groups. Consequently, the total food consumption during successive age (RAt) increased from 117.1 g/fish (age: 0.1 - 0.5 y) to 2791.1 g/fish (age: 3.0 - 3.5 y). However, the feeding rate (R/w) decreased with advancing age from 5.8% body weight/d to 4.0% bw/d with a mean of 4.7% bw/d. The R/w was negatively correlated with W with the following relationship (Fig. 2): log R/w = 0.925-0.120 log W; r = -0.952.

N.japonicus attained an average body weight of 65.0, 217.5,341.5 and 384.0 g at the age of 1,2,3 and 3.5 years respectively (Table 2). The weight increment (AW) increased with increasing ration from 27g (RAt: 117.1 g) to 79 g (RAt: 1133.9 g) but subsequently decreased to 35 g (RAt: 2791.9 g) (Fig. 3). The growth rate (W/w) decreased with advancing age from 1.34% bw/d (age: 0.1 - 0.5 y) to 0.05% bw/d (age: 3.0 - 3.5 y) with a mean of 0.31% bw/d. The W/w was negatively correlated with W with the following relationship (Fig. 2):

Log W/w = 1.291 - 0.886 log W; r = - 0.974.

The production efficiency of *N.japonicus* was estimated as 0.06 (Table 2), i.e., 6% of the consumed food was converted for growth. The K decreased with advancing age, from 0.23 (age: 0.1 - 0.5 y) to 0.01 (age: 3.0 - 3.5 y). As the feeding rate (R/w) also decreased with advancing age, the R/w and K were positively correlated with the following relationship:

LogR/w = - 5.879+6.825 log K; r = 0.921.

The annual average number and weight of *N.japonicus* landed at Veraval fisheries harbour were 17.1 million and 18051, during 1989-1991. It is estimated that the annual food consumption of the exploited population was 30,7351. Of the 6.5 kg of food in the stomachs of *N.japonicus* sample, food items of 2.5 kg only could be identified to group level. *Acetes* spp. contributed to 40.5% of the stomach contents, followed by penaeid prawns (24.0%). It is estimated that the

TABLE 1. *Food consumption by* N.japonicus *off Veraval*

Length (mm)	Age(Y)	Fish sample (n)	Fish sample (kg)	Food (kg)	R (g/fish/d)	RAt (g/fish)
50-122	0.1-0.5*	390	6.4	0.374	0.96	117.1
123-188	0.5-1.0	460	29.9	1.640	3.55	646.1
189-233	1.0-1.5	164	22.7	1.022	6.23	1133.9
234-266	1.5-2.0	152	33.0	1.485	9.77	1778.1
267-287	2.0-2.5	91	26.0	1.067	11.73	2134.9
288-303	2.5-3.0	56	19.1	0.821	14.66	2668.1
304-313	3.0-3.5	5	1.9	0.077	15.34	2791.9
50-313	0.1-3.5	1318	139	6.486	4.92	6130.5

*As the population below the age of 0.1 year was not exploited, At for the smallest age group was considered as 0.4 y.

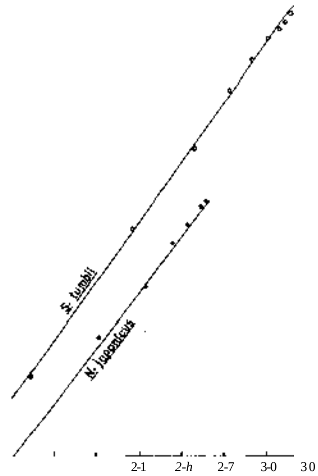

Fig. 1 Relationship between log body weight (W, in g) and log daily food consumption (R, in g/fish/day) of *N.japonicus* and *S.tumbil*

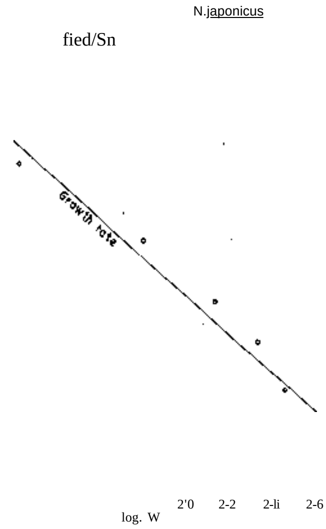

Fig. 2. Relationship between log body weight (W, in g) and log feeding rate (% body weight/day) and log growth rate (% body weight/day) *of N.japonicus.*

exploited population consumed 12,449 and 7,376 t of *Acetes* and penaeid prawns, respectively. The finfishes contributed 17.1 % to the food and the cephalopods, 11.1%.

S. *tumbil*

The R of *S.tumbil* increased with advancing age, from 2.38 g/fish/d (age: 0.2 to 0.5 y) to 119.22 g/fish/d (age: 4.0 - 4.5 y) (Table 3). In other words, the R increased with increasing W with the following linear relationship (Fig. 1):

Log R = - 0.847 + 0.922 log W; r =0.997.

Consequently, the RAt increased from 0.2 kg/fish (age: 0.2 - 0.5 y) to 21.7 kg/fish (age: 4.0 - 4.5 y). However, the R/w decreased with advancing age from 10.8% bw/d to 7.8% bw/d with a mean of 9.1% bw/d. The R/w was negatively correlated with W with the following relationship (Fig.4):

TABLE 2. *Production efficiency* o/"N.japonicus *offVeraval*

Age(Y)	Weight (W) (g)	W (g)	AW (g)	AW/d (mg)	RAtfAW (g)	AW/RAt (g)
0.1-0.5	3-30	16.5	27	221	4.3	0.23
0.5-1.0	31-99	65.0	69	379	9.4	0.11
1.0-1.5	100-178	139.0	79	434	14.4	0.07
1.5-2.0	179-256	217.5	78	429	22.8	0.04
2.0-2.5	257-316	286.5	60	330	35.6	0.03
2.5-3.0	317-366	341.5	50	275	53.4	0.02
3.0-3.5	367-401	384.0	35	192	79.8	0.01
0.1-3.5	3-401	105.0	398	321	15.4	0.06

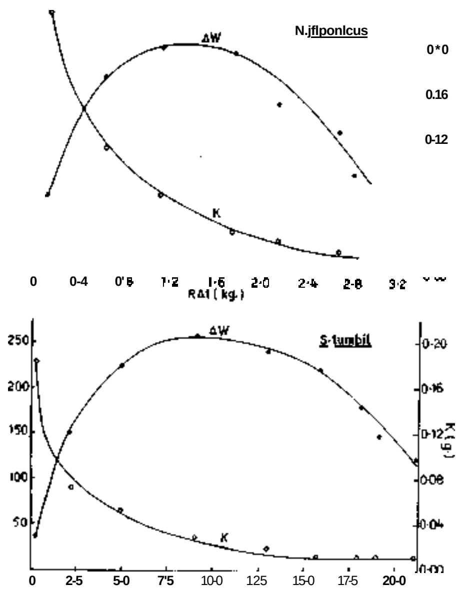

Fig.3. Relationship between food consumption (RAt) of different age groups and weight increment (AW) and production efficiency (K) of *N.japonicus* and *S.tumbil;* the curves are eyefit.

LogR/w =1.151-0.077 log W ; r = -0.924.

S.tumbil attained an average body weight of 115,543,1022,1392.5 and 1528.5 g at the age of 1, 2, 3, 4 and 4.5 y, respectively (Table 4). The AW increased with increasing ration from 36 g RAt: 0.2 kg) to 256 g (RAt: 9.1 kg) but subsequently decreased to 123 g (RAt: 21.7 kg) (Fig. 3). The growth rate (W/w) decreased with advancing age from 1.80% bwld to 0.04% bw/d with a mean of 0.31% bw/d. The W/w was negatively correlated with W with the following relationship (Fig. 4):

Log W/w = 1.547 - 0.841 log W; r = - 0.958.

The K of *S.tumbil* was estimated as 0.03 (Table 4), i.e., 3% of the consumed food was converted for growth. The K decreased with advancing age from 0.18 to 0.01. As the feeding rate also decreased with advancing age, the R/w and K were positively correlated with the following relationship:

LogR/w = -9.486+8.343 logK; r = 0.935.

TABLE 3. *Food consumption by* S.tumbil *offVeraval*

Length (mm)	Age (Y)	Fish sample (n)	(kg)	Food (kg)	R (g/fish/d)	RAt (kg/fish)
70-159	0.2-0.5*	78	1.7	0.18	2.38	0.2
160-268	0.5-1.0	375	43.1	4.31	11.50	2.1
269-350	1.0-1.5	429	129.6	11.66	27.18	4.9
351-412	1.5-2.0	286	155.3	14.29	50.00	9.1
413-457	2.0-2.5	34	26.9	2.42	71.23	13
458-492	2.5-3.0	35	35.8	3.04	86.87	15.8
493-518	3.0-3.5	3	3.7	0.30	98.04	17.8
519-537	3.5-4.0	3	4.2	0.32	104.44	19
538-552	4.0-4.5	2	3.1	0.24	119.22	21.7
70-552	0.2-4.5	1245	403.4	36.76	29.48	46.3

•As the population below the age of 0.2 year was not exploited,
A t for the smallest exploited age group was considered as 0.3 y.

TABLE 4. *Production efficiency* o/S.tumbil *offVeraval*

Age(y)	Weight (W) (g)	W (g)	AW (g)	AW/d (mg)	RAt/AW (g)	AW/RAt (g)
0.2-0.5	4-40	22.0	36	396	5.6	0.18
0.5-1.0	41-189	115.0	148	813	14.2	0.07
1.0-1.5	190-414	302.0	224	1231	21.9	0.05
1.5-2.0	415-671	543.0	256	1407	35.5	0.03
2.0-2.5	672-911	791.5	239	1313	54.4	0.02
2.5-3.0	912-1132	1022.0	220	1209	71.8	0.01
3.0-3.5	1133-1318	1225.5	185	1016	96.2	0.01
3.5-4.0	1319-1466	1392.5	147	808	129.3	0.01
4.0-4.5	1467-1590	1528.5	123	676	176.4	0.01
0.2-4.5	4-1590	324.0	1578	1005	29.3	0.03

The annual average number and weight of *S. tumbil* landed were 2.8 million and 9081 (Table 5). The estimated annual consumption of the exploited population was 30,188 t. Of the 36.8 kg of food in the stomachs of the samples, 9.8 kg of food could be identified to group level. Cephalopods, particularly the squids (26.4%) contributed the maximum share to the food, followed by the penaeid prawns (13.1%) (Table 6). Teleosts contributed 44.7%. Cannibalism was high (10.3%) among*S.tumbil*.

TABLE 5. *Annual average landings and food consumption* o/"N.japonicus *and* S.tumbil.

Age(y)	*N.japonicus*				*S.tumbil*			
	Annual catch		Food intake (t)		Annual catch		Food intake (t)	
	No(000)	Wt(t)	Daily	Annual	No(000)	Wt(t)	Daily	Annual
0.1-0.5*	5068	83.6	4.8	1752	175	3.9	0.4	146
0.5-1.0	5980	385.7	21.2	7738	843	96.9	9.7	3541
1.0-1.5	2132	295.3	13.3	4855	964	291.1	26.2	9563
1.5-2.0	1974	428.4	19.3	7045	643	349.1	32.1	11717
2.0-2.5	1185	338.9	13.9	5074	76	60.2	5.4	1971
2.5-3.0	728	248.2	10.7	.3906	79	80.7	6.9	2519
3.0-3.5	65	24.9	1.0	365	7	8.6	0.7	256
3.5-4.0	0	0.0	0.0	0	7	9.7	0.7	256
4.0-4.5	0	0.0	0.0	0	5	7.6	0.6	219
Total	17132	1805	84.2	30735	2799	907.8	82.7	30188

* youngest exploited age group *of S.tumbil* was 0.2-0.5 y

Discussion

The present study (i) assumes an uninterrupted food supply throughout the year, (ii) considers that the fishes attain daily satiation, (iii) ignores the rate of gastric evacuation, (iv) does not consider the effects of biotic and abiotic factors on food intake, and (v) does not consider the unexploited portion of the population. Nevertheless, the information gained is expected to set a beginning for evolving a new ecosystem approach for the coastal fisheries management.

The feeding and growth rates of *N.japonicus* and *S.tumbil* are within the range of values reported in the earlier studies for tropical fishes. Consolidating the values available on the feeding rates of 12 species of fishes, Pandian and Vivekanandan (1985) concluded that the feeding rate of tropical fishes range from 4.1 to 36.0% bw/d (mean: 16.7% bw/d) and the production efficiency from 0.1 to 0.2 (mean: 0.15). The mean R/w and Rvalues estimated in the present study are on the lower side of the range of values due to the following reasons: (i) The values reported by Pandian and Vivekanandan (1985) were obtained from laboratory experiments, where the fishes were offered food, ad *libitum,* (ii) Most of those experiments were conducted on young fishes for a limited duration, resulting in higher rates of feeding and growth. Comparable data on the R/w, W/w and K extending throughout the life of finfishes in Indian waters are not available.

With advancing age, the reduction in

TABLE 6. *Food composition* o/"N.japonicus *and* S.tumbil

Food item	*N.japonicus*			*S.tumbil*		
	Food in sample		Annual intake (t)	Food wt in sample		Annual intake (t)
	(g)	%		(g)	%	
Sciaenids	105.6	4.2	1290	682.4	7.0	2113
Silverbellies	90.5	3.6	1106	0.0	0.0	0
Apogon spp.	80.4	3.2	983	0.0	0.0	0
Carangids	80.4	3.2	983	0.0	0.0	0
Threadfin bre-ams	72.9	2.9	891	536.1	5.5	1660
Lizardfishes	0.0	0.0	0	1004.0	10.3	3109
Ribbonfishes	0.0	0.0	0	896.8	9.2	2777
Scads	0.0	0.0	0	731.1	7.5	2264
Flatfishes	0.0	0.0	0	506.9	5.2	1570
Penaeid praw-ns	603.4	24.0	7376	1277.0	13.1	3955
Acetes spp.	1018.2	40.5	12449	633.6	6.5	1962
Crabs	100.6	4.0	1228	0.0	0.0	0
Squids	145.8	5.8	1783	2573.5	26.4	7970
Cuttlefishes	133.2	5.3	1629	604.4	6.2	1872
Others*	83.0	3.3	1014	302.2	3.1	936

*include few other groups which were identified but were represented in less quantity gravimetrically.

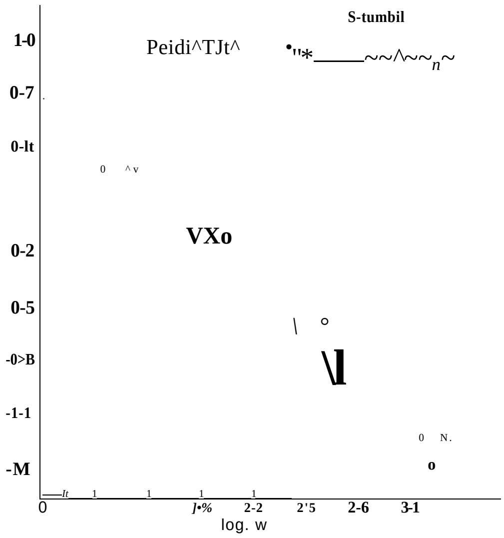

Fig. 4. Relationship between log body weight (W, in g) and log feeding rate (% body weight/day) and log growth rate (% body weight/day) of *S.tumbil*

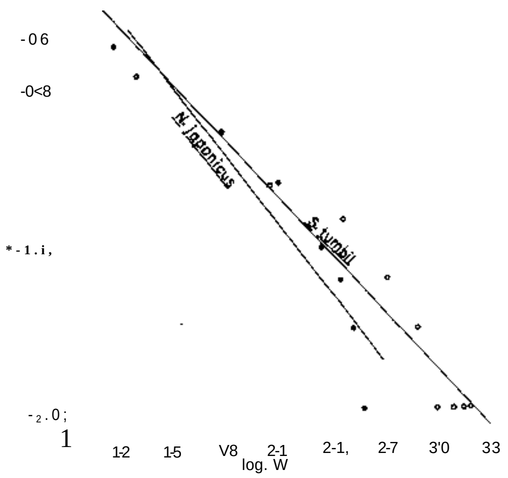

Fig. 5. Relationship between log body weight (W, in g) and log production efficiency (K) of *N.japonicus* and *S.tumbil.*

growth rate was more conspicuous than the reduction in feeding rate resulting in very high utilization of food items from the ecosystem by old fishes but with a low food conversion ratio. Paloheimo and Dickie (1965) found that the K decreases linearly with advancing age and increasing body weight of fishes. The older fishes expend more energy on metabolic processes such as absorption, excretion, respiration and reproduction (Vivekanandan, 1977). In the present study, the youngest *N.japonicus* (age: 0.1 - 0.5 y), for instance, converted 23% of the consumed food for growth and expended 77% towards absorption, excretion and respiration. The old fishes (3.0 - 3.5 y) converted only 1% of the consumed food towards growth and expended as high as 99% on metabolism.

Comparison of food utilisation of *N.japonicus* and *S.tumbil* reveals the following features: (i) The feeding rate of S. *tumbil* (9.1% bw/d) is nearly twice than that of *N.japonicus* (4.7% bw/d). (ii) The growth rate of both the species is equal (0.31% bw/d). (hi) Consequently, the K of *N.japonicus* (0.06) is twice that of *S. tumbil* (0.03). For maximising the K, the carnivores select the right type and size of prey that is easy to be handled. Preys which are > 0.1% of the predator's size increase the handling time and incur heavy loss of profitability to the predator (Pandian and Vivekanandan, 1990). Unlike *N. japonicus*, *S.tumbil* often predate very large prey which are more than 1% of the predator's size. The capacity of the lizardfish to ingest very large prey was observed in the case of one individual (total length: 330 mm), which had predated another *S.tumbil* (TL: 205 mm) measuring 62% of its length and 15% of its weight. *S.undosqamis* was reported to predate on prey which was about 50% of its length and 15% of its weight (Bingel, 1988). As the size of prey predated by the lizardfish far exceed the optimum size reported for other teleosts, it is likely that the lizardfish spend more energy on predating large prey.

In the complex trophic levels in an ecosystem, intense predation results in competition for food. The competition will be intense between two or more species occupy the same space and consume the same food concurrently. However, this need not be always true. Different species of fishes have evolved individual predatory strategies so that they may never directly contact each other (Sainsbury, 1982). Though *N.japonicus* and *S.tumbil* inhabit the same area and are exposed to the availability of the same prey, the food preference of the two species is distinctly different. Whereas crustaceans contribute 68.5% of the food *of N.japonicus,* teleosts and cephalopods contribute 77.3% of the *food of S.tumbil.*

The estimation that 60,9231 of food is consumed in a year by the exploited biomass (2713 t) of *N.japonicus* and *S.tumbil* indicates the utilization of a very high quantity of food from the ecosystem. These two predators consumed food almost equal to the annual trawl landings (67,049 t during 1989; Vivekanandan *et al.,* 1994) at Veraval. The consumption of prey ingested by the two predators exceeded the annual landings of the corresponding prey. For instance, the predators consumed 11,331, 14,411 and 13,254 t of penaeid prawns, *Acetes* spp and cephalopods, respectively (Table 6). The corresponding annual landings of the prey groups were 3,190,13,813 and 3,2131 during 1988-1990 at Veraval (Vivekanandan *et al.,* 1994). In the Baltic sea, a single species of cod consumes herring (56,000 to 95,000 t/year) as food equivalent to or higher than the landings (66,000 t) (Bagge, 1981). In the Barents sea, 1 million tonnes of cod consumed 2,30,0001 of prawns in one year, which was considerably more than the commercial catch (Ponomarenko and Yaragina, 1984). The utilization of large quantity of prey due to predation calls for addressing the following two vital features while assessing the recruitment and natural mortality offish populations: (i) As the predators consume small fish/prey, recruitment to the fishery is largely determined by predation (Laevastu and Favorite, 1988). (ii) Keeping in view, the apex predators such as sharks, ribbon fishes, seer fishes and tunas in the ecosystem and the food consumption by the two predators equal or more than the landings, the total biomass lost due to predation is enormous. It appears that the natural mortality due to predation may be several times higher than the fishing mortality in marine ecosystems. Gravimetric and numeric estimations of food consumption of several fish species are required for reliable estimates of natural mortalities and comparison of natural and fishing mortalities.

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