Journal of Applied and Natural Science 7 (2) : 916 - 921 (2015)

JANS

Economic loss assessment on juvenile fish catch due to forced non-selectivity in a selective fishing gear, gillnet along Mumbai coast, India

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Received: May 21, 2015; Revised received: October 18, 2015; Accepted: November 12, 2015

Abstract: A study on quantity and value of juvenile fish landings was carried out in the gillnet fishery of three selected landing centers along Mumbai coast viz., Versova, Cuff Parade and Mahim in India using Out board motors (OBM), Inboard motors (IBM) and non-motorised gillnetters respectively. The data on the quantity and value of landed juveniles were collected and analysed to reach a consensus on the gross economic loss on account of juvenile fishing. A bio-economic model was used to estimate economic loss due to juvenile fishing of 18 commercially important species of finfish and shellfish. A huge economic loss was recorded due to fishing of juveniles of 18 species by three different gillnet sectors. The analysis indicated that IBM gillnetters at Cuff Parade incurred maximum loss of Rs. 62.26 crores with major contribution from juveniles of seerfish followed by non-motorised gillnetter (Rs.29.98 crores) at Mahim and 25.33 crores in OBM gillnetters at Versova.

Keywords: Economic loss, Gillnet, Juvenile fishing, Mumbai coast

INTRODUCTION

In open access marine fisheries, the non targeted catches in the form of juvenile are detrimental, as this would reduce future yield and subsequent recruitment to the fishery The proliferating impact of juvenile fishing is much more intense in multi-gear and multi species fishery where intra and inter sectoral conflicts exists (Najmudeen and Sathiadhas, 2008). Growth overfishing occurs when the fishery targets fishes of a size below the optimal harvestable size (Diamond *et al.*, 1999). So sustainable fisheries management generally requires fishing gears which retain large fish while allowing juveniles to escape (Armstrong *et al.*, 1990).

The proportion of undersized fishes in total catch is high in a multispecies fishery where various kinds of gear and crafts are competitively employed to target different varieties of fishes (Sivasubramaniam, 1990; Sujatha, 1996). The recent shift in the employed fishing methods in inshore fisheries has led to a remarkable increase in fish production on account of bycatch and juvenile catch (Radhakrishnan *et al.*, 2006). However, this will have negative impacts in the long run and it will ultimately reduce the fish catch. There are several reasons for the unawareness among the fishermen regarding this concept.

Indian marine ecosystem is tropical multi-species fisheries characterized by a heterogeneous fishery management systems; formal and countless informal agreements and the conflicts management systems that are in practice in the different maritime states of the country (Pido *et al.*, 1996). It is obvious that the fishing fleet of our country has witnessed the juvenile fishing from different gears. However, there is a paucity of data on juvenile catch especially from gillnet fisheries and there is an inconsistency in the available data (MRAG, 2012). Gillnetting has become popular among fishers being less capital intensive, selectively operated depending on availability and demand and can be operated at areas where bottom is not suitable for trawling. Among the gear wise contribution to all India marine landings, the gillnets contributed 21% with 6% mechanised and 15% motorised sector during 2007 (Ramani et al., 2010). State wise gillnet contribution to the total marine fish landings during 2012 was maximum of Tamil Nadu (16.2%), followed by Andhra Pradesh (14%), Gujarat (13%), Maharashtra (7.3%), Kerala (6.2%) and Karnataka (3.4%) (Anonymous, 2013).

Maharashtra with 720 km of coastline along with five maritime districts is an important maritime state with respect to marine fish production. The marine fish landings in Maharashtra during 2011 have been estimated provisionally as 4.13 lakh t. The mechanised (12, 154 units) and non-mechanised (2,292) gillnet fleet contributes 11.2% of the total catch (Anonymous, 2012). Mumbai district, has alone shared 1.43 lakh t which is 32% of the total marine fish production of Maharashtra (Anonymous, 2011). This indicates that Mumbai coast is one of the most important fishing grounds of the state. Since 1980's many need based changes have taken place like motorization, gear material substitution, methods of operation, resource specific gear, use of colored webbing. It is sure that these improved methods has resulted in increased fish production from the coast. A notable change in the gillnet fishing is the popular use of specific mesh sizes for specific resources.

Though gillnets are found to be a selective fishing gear, the usage by considerably reducing the mesh size makes it as a non-selective gear. This conversion has resulted in the increased landings of juveniles in the gear catch. However, fishermen would be reluctant to hear and understand the ecological impacts in this line. The best method for making the fishermen aware about the concern will be presenting the same on economic terms. In this context, an effort has been made to assess the economic damage caused on account of juvenile catch. To the best of our knowledge this is the first attempt to analyze the extent of juveniles landed and their economic loss in gillnet fishing by three fleets of gillnetters viz., IBM, OBM, and non-motorised.

MATERIALS AND METHODS

Maharashtra is a maritime state situated on the west coast of India endowed with 720 km of coast line. Thane, Greater Mumbai, Raigad, Ratnagiri and Sindhudurg are the five coastal districts of Maharashtra. Versova, Mahim and Cuff Parade, are the active fish landing centres of gillnetters of Mumbai. Hence, these three centres were selected for the study. The geographical positions of Versova (19o14'24'' N latitude and 72o80'28'' E longitude), Mahim (19o 04'50" N latitude and 72o 83'74'' E longitude) and Cuff Parade (18o90'87'' N latitude and 72o82'57'' E longitude).

Different type of gillnets varying in mesh sizes from 14 and 150 mm were used to catch different varieties of fish and shellfish. Multifilament polyamide (nylon) gillnets mostly operated by mechanised (IBM) gillnetters were generally used for catching seerfish, tuna and white sardine and monofilament nylon gillnets mostly operated by motorised (OBM) gillnetters were mainly targeted for catching mackerel, hilsa, sardine, pomfret and carangids. Non-motorised gillnetters operate nylon monofilament gillnets for solefish, catfish, sciaenids, sharks and carangids.

Data were collected weekly from the IBM, OBM and non-motorised gillnetters operated from Cuff Parade, Versova and Mahim landing centres respectively from 1st December 2010 to 30th November, 2011 except during the fishing period. On the days of observation, a representative sample (minimum 1000 g) from the catch was taken. The total quantity of a commercial species landed on the day of observation were noted after sorting and grading by the fishermen. Samples were brought to the laboratory and the total length was measured to the nearest mm to categorize landings into adults and juveniles. Specimens having total length below the length at first maturity were classified as juveniles and others as adults. To get exact information on juvenile and adult finfish and shell fish, the length at first maturity of species was collected from secondary sources of data (Mohamed *et al*., 2008; Sawant, 2011).

The total catch was divided by the sample weight and were raised using a factor to arrive at the total weight of juvenile and adults on a particular day and for the month considering 20 days fishing in a month. Thus, the estimations were also made for the month wise catch of juveniles and adults with respect to OBM, IBM and non-motorised gillnetters (Sekharan, 1962). The quantity of juveniles landed in each fishing unit was recorded along with corresponding price from the landing centre. The wholesale price of juveniles and adult of each species on each sampling day was recorded from fishermen/commission agents/fish retailers by interviewing them at the landing centres.

Landing centre price of adult fish varies significantly from the price of juvenile of the same variety. The differential ratio was estimated it should be read as no price difference (or no economic cost) if the ratio is '1'. Juveniles of certain species such as Scombermorus commerson, Scomberomorus guttatus, Farmio. niger and Rastrelliger kanagurta fetch better price due to its high demand in domestic as well as international markets (Fig. 1).

Adult quantity corresponding to 1 kg of juveniles landed was worked out by the formula given by Najmudeen and Sathiadas (2008).

$$Q_{\mathrm{A}} = \left(\frac{(1000/w)W}{1000}\right)(1-M)$$

Q_A = adult fish quantity corresponding to 1 kilogram of juvenile fish after a period of t years

W= weight of the individual adult fish after a period of t years

ω= individual weight of juvenile of the species in gram.

M= Natural mortality

The mortality rates of individual fish species were collected from secondary sources of data for estimating the biomass of fish corresponding to the quantity of juveniles landed, assuming they were left in the water to grow up to their size at first maturity. The values of M (natural mortality) and Z (total mortality) have been taken from the secondary sources of data available on these species (Mohamed *et al.*, 2008 and Sawant, 2011). Using the length-weight relationship, weights of the selected species were calculated using the length values.

Fitting of the model: The length-weight relationship in the form of W= a L^b (where 'W' is the weight of fish, 'L' denotes the length and 'a' the constant and 'b'

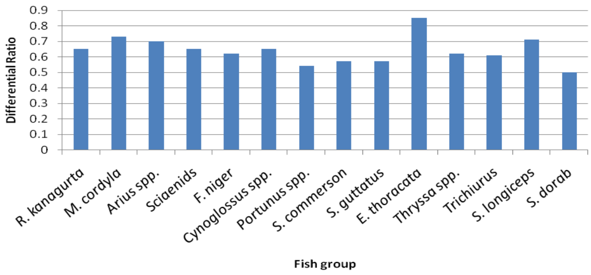


Fig. 1. *Calculated differential ratio of landing centre prices of juveniles and marketable size of the commercially important fish groups along Mumbai coast, Maharashtra.*

the exponent) was fitted. With this process, the total weight of each species landed by gillnetters from all three centres was computed. The corresponding price of adult and juveniles was fed in the table and this resulted in getting separate price for the adult and juvenile population of each species. The bio-economic model developed by Najmudeen and Sathiadas (2008) was followed to calculate the economic loss due to juvenile fishing.

$$\text{EL} = \left(\frac{\sum_{i=1}^{n} C_i Q_i/(1+\delta)^t}{n}\right) - \left(\frac{\sum_{i=1}^{n} c_i q_i}{n}\right)$$

Where EL= average economic loss for the quantity of juveniles landed per unit per fishing trip

C_i = annual average wholesale price of the adult fish of the same species of juvenile

c_i = annual average wholesale price of the of juvenile fish

Q_i = Adult biomass was for each species from the quantity of the juveniles landed

q_i = with an assumption that, if the juveniles landed are allowed for a period of 't' years

n = represents the total number of boats,

δ = is the standard discount rate (%).

RESULTS AND DISCUSSION

The economic deficit due to the capture of juveniles of different species was worked out for three different sectors viz., IBM, OBM and non-motorised fishing craft of gillnetters. IBM gillnet unit, non-motorised gillnet unit and OBM gillnet unit showed an average economic deficit of Rs. 68.07 lakhs, Rs. 24.98 lakhs and Rs.11.01 lakhs respectively. In total, 90 IBM gillnetters of Cuff Parade have incurred an annual economic deficit of Rs. 61.26 crores. This fleet was followed by the 120 non-motorised gillnetter fleet of Mahim with an economic deficit Rs.29.98 crores. Moreover, 230 OBM gillnet fleet of Versova has incurred an annual economic deficit of Rs. 25.33 crores. The total overall annual economic deficit due to juvenile fishing of 18 commercially important species by three sectors of gillnetters viz., IBM (56%), OBM (20%) and non-motorised (24%) units operated from Cuff Parade, Versova and Mahim was estimated around Rs. 116.58 crores per annum (Table 1).

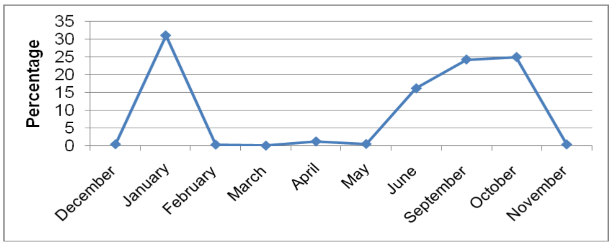
IBM gillnetter

Species wise economic deficit: Total economic deficit of 11 commercially important species from Cuff Parade caught by IBM gillnetters for one fishing season was Rs. 61.26 crores. The maximum economic deficit was estimated for S. guttatus (Rs.37.20 crores), followed by S. commerson (Rs.20.83 crores), Escualosa thoracata (Rs. 13.93 crores), Rastrelliger kanagurta (Rs.51.35 lakhs), Scomberoides tol (Rs.44.43 lakhs), Megalaspis cordyla (Rs. 22.48 lakhs), Sardinella gibbosa, (Rs.22.54 lakhs), Arius caelatus (Rs.17.52 lakhs), Trichiures leptures (Rs.17.56 lakhs), Chirocentrus dorab (Rs.39.80 lakhs), and the least was estimated for Johnieops sina (Rs.4.22 lakhs) (Table 2).

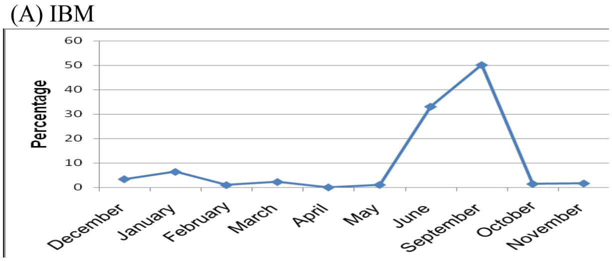
Month wise economic deficit: Month wise economic deficit incurred due to juvenile fishing by IBM gillnet fleet of Cuff Parade is shown in Fig.(2 A). The highest economic deficit was estimated in January, (Rs.19.08 crores), followed by October (Rs.15.35 crores), September (Rs.14.92 crores), June (Rs.9.94 crores), April (Rs.78.44 crores), May (Rs. 34.07 crores), December (Rs.29.82 crores), February (Rs. 22.01 crores) and the least in March with total contribution of Rs. 58.68 lakhs.

OBM gillnetter

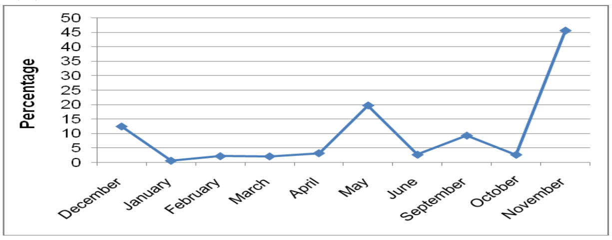
Species wise economic deficit: Detailed analysis was carried out to find out the quantities of juveniles landed and their economic deficit by OBM gillnetters from Versova. Altogether juveniles of 12 commercially important fish and shellfish varieties were captured. The total economic deficit from Versova for 12 species landed by OBM gillnet fleet was Rs.25.33



(A) IBM



(B) OBM



(C) Non motorised

Fig. 2. *Month wise percentage contribution to total economic deficit of three different gillnet units due to juvenile fishing along Mumbai coast.*

Table 1. Annual average economic deficit of juvenile fishing along Mumbai coast (Rs. per annum).

Gillnet sectors	Total number of fishing units	Economic deficit (Rs. crores)
Inboard motors (IBM)	90	61.26
Outboard motors (OBM)	230	29.98
Non-motorised	120	25.33
Total	440	116.57

crores. S. commerson contributed maximum economic deficit of Rs. 19.89 crores. This was followed by A. caelatus (Rs. 1.24 crores), Johnieops vogleri of (Rs. 1.00 crores), E. thoracata (Rs. 86.69 lakhs), Carcharhinus limbatus (Rs. 51.93 lakhs), R. kanagurta (Rs. 42.73 lakhs), Otolithus cuvieri (Rs. 38.39 lakhs), J. sina (Rs. 33.93 lakhs), F. niger (Rs. 22.56 lakhs), Megalaspis cordyla Rs. (15.73 lakhs) and Charybdis orientalis (Rs. 15.70 lakhs). The lowest juvenile economic deficit was found to be for T. lepturus with a value of Rs. 11. 75 lakhs (Table 3).

Month wise economic deficit: Month wise economic deficit incurred for OBM gillnet fleet from Versova was found to be maximum in September with a loss of Rs. 12.71 crores. The second higher economic deficit was recorded in June with the deficit of Rs. 8.39 crores. This was followed by January (Rs.1.62 crores), December (Rs. 87.68 lakhs), March (Rs. 58.70 lakhs), November (Rs.43.44 lakhs), October (Rs. 37.70 lakhs), May (Rs. 2.83 lakhs) and February (Rs.2.45 lakhs). The lowest economic deficit was found in April with Rs.2.23 lakhs (Fig. 2 B).

Non-motorised gillnetters

Species wise economic deficit: The species wise economic deficit due to juvenile fishing by 120 vessels operating from Mahim centre was analysed and was found that maximum deficit was recorded by R. kanagurta with Rs. 16.93 crores. This was followed by S. commerson (Rs. 6.2 crores), A. caelatus (Rs. 3.79 crores), C. limbatus (Rs. 2.17 crores), M. cordyla (Rs.24.92 lakhs), Pampus argenteus (Rs. 21.17 lakhs), J. sina (Rs. 10.94 lakhs), T. lepturus (Rs.10.11 lakhs) and Otolithus ruber (Rs. 6.59 lakhs). The lowest was observed for J. vogleri with total deficit of Rs. 5.25 lakhs (Table 4).

Month wise economic deficit: Month wise economic deficit of non-motorised vessels in Mahim centre is shown in (Fig.2 C). Maximum economic deficit was estimated in November with the economic deficit of Rs.13.67 crores with maximum loss from catching juveniles of R. kanagurta. This was followed by May (Rs. 5.90 crores), December (Rs.3.71 crores), September (Rs. 2.76 crores), April (Rs. 94.29 lakhs), June (Rs.78.93 lakhs), February (Rs. 63. 29 lakhs) and March (Rs. 61.17 lakhs). The lowest economic deficit of Rs. 16.14 lakhs was found in January.

In the present study, an attempt was made to calculate the annual economic deficit generated by gillnetters along Mumbai coast. It involves the estimates of an-

Table 2. Economic loss due to different species in IBM along Mumbai coast.

Species	Economic loss in Rs. (crores*/ lakhs**)	Economic deficit (%)
S. guttatus	37.20 *	60.72
S. commerson	20.83*	34.00
E. thoracata	13.93*	2.27
R. kanagurta	51.35 **	0.84
S. tol	44.43**	0.73
M. cordyla	22.48**	0.37
S. gibbosa	22.54 **	0.37
caelatus	17.52**	0.29
T. leptures	17.56**	0.29
C. dorab	39.80**	0.06
J. sina	4.22**	0.07

*in crores, **in lakhs

nual economic deficit due to juvenile fishing of altogether 18 commercial species. The annual economic deficits for each fishing unit of IBM gillnetter, OBM gillnetter and non motorised gillnetter were estimated as 68.07 lakhs, 11.01 lakhs and 24.98 lakhs respectively. Similarly, the annual economic deficit from IBM fleet (90 units), OBM fleet (230 units) and non-motorised fleet (120) were estimated to be 61.26 crores, 25.33 crores and 29.98 crores respectively. In IBM and OBM fleets, the highest economic deficit was due to capture of juvenile of Scomberomorus spp. This may probably be due to small mesh size (100-150 mm) used extensively to exploit Scomberomorus species which results in landings of high quantity of juveniles. The optimum mesh size for *S. commerson* is 152 mm (Sulochanan *et al*., 1975) and 104 mm for S. guttatus (Sreekrishna *et al.*, 1972). The maximum economic deficit was due to juveniles of this species which get premium price due to its high demand in domestic and international markets.

The juveniles of *Arius* spp. were the second largest group contributing major share to the economic deficit of OBM sector because of juveniles caught as non target catch in the gillnets of mesh size 28-32 mm targeted for croakers. Similarly in non- motorised gillnetters, the maximum economic deficit was contributed by juveniles of *R. kanagurta* because of small mesh sizes (38-46 mm) used to exploit the mackerel fishery which is far less than the optimum mesh size of 50 mm for *R. kanagurta* worked out by Mathai *et al.* (1993).

The sector wise analysis of economic deficit all the three fleets showed that IBM fleet contributed maximum share of 56% to the total. This may be attributed to the usage of different mesh sizes (many of which smaller than optimum) simultaneously which will change its action in to a non selective gear (Thomas *et al*., 2005). Hence, the juvenile catches were high in this fleet in comparison with other fleets. There are reports from different parts of the country regarding the use of multi meshed gillnets especially for seer and tuna (Thomas *et al*., 2005). Such types of nets are commonly operated for seerfish along Mumbai coast.

Table 3. Economic loss due to different species in OBM along Mumbai coast.

Species	Economic loss in Rs. (crores*/ lakhs**)	Economic deficit (%)
S. commerson	19.98*	78.52
caelatus	1.24*	4.90
J. vogleri	1.00*	3.97
E. thoracata	86.79**	3.42
limbatus	51.93 **	2.05
R. kanagurta	42.73**	1.69
O. cuvieri	38.39**	1.52
J. sina	33.93**	1.34
F. niger	22.56 **	0.89
M. cordyla	15.73 **	0.62
C. orientalis	15.70 **	0.62
T. leptures	11.75 **	0.46

*in crores, **in lakhs

Non-motorised gillnetters contributed 24% of the total economic deficit. This fleet was concentrated in the inshore areas where the breeding, feeding and nursery grounds as well as migratory routes for most of the commercial fish resources exist. Besides, the rough weather conditions during monsoon force the non-motorised fishermen to operate in the near shore areas. OBM gillnetters contributed 20% of the total economic deficit which was comparatively less as a result of lower quantity of juvenile landings probably due to use of optimum mesh size for target species.

The highest economic deficit due to capture of juveniles was in January (Rs.19.08 crores) for IBM, in September for OBM (Rs. 12.71 crores), and in November (Rs. 13.67 crores) for non-motorised gillnetters. Taking all the three landing sectors, it was observed that maximum economic deficit occurred in Autumn and Winter seasons i.e. post monsoon period because most of fishes breed during monsoon period (Rajagopalan *et al.*, 1992). So from conservation point of view use of mesh sizes smaller than the optimum sizes need to be regulated during post monsoon period.

The bio-economic model that has been used in the present study takes recruitment as constant. This also happens to be one of the rigorous assumptions of the Beverton and Holt's (1957) dynamics pool model. This model also does not take into account of the discards that is thrown in the sea itself and takes only the one that is landed at the fish landing centres. The other constraint being the data is collected over a period of one year except during fishing ban. At least data for a period of 2 - 3 years would have yielded better results and this prediction would have been nearer to reality. So the present study highlight that the negative economic impact of juvenile fishing. There are only few reports pertaining to economic impacts of bycatch and discards as a result of catching juveniles (Sivasubramaniam, 1990; Sujatha, 1996; Hall *et al.*, 2000; Kaiser and De Groot, 2000; Kelleher, 2005). In India, specific studies were initiated by Sathiadas *et al.*

Table 4. Economic loss due to different species in non-motorised gillnetters along Mumbai coast.

Species	Economic loss in (Rs.) in crores/lakhs	Economic deficit (%)
R. kanagurta	16.93 *	56.60
S. commerson	6.20 *	20.98
caelatus	3.79 *	12.65
C. limbatus	2.17 *	7.24
M. cordyla	24.92 **	0.83
P. argenteus	21.17 **	0.71
J. sina	10.94 **	0.37
T. leptures	10.11 **	0.34
O. ruber	6.59 **	0.22
J. vogleri	5.25 **	0.18

*in crores, **in lakhs

(2005), Najmudeen and Sathiadas (2008) and Mohamad *et al.* (2009) in which they have analysed the economic impact of juvenile fishing in multi-gear multispecies fishery *of* Kerala. The economic loss on account of catching juvenile sciaenid species in trawl fishery along Mumbai coast was estimated by Kamei *et al.* (2013). It is highly cumbersome to quantify the bycatch in the form of juveniles landed by different types of fleets. However, many previous studies have analysed the trawl landings of the south west coast of India to quantify the incidence of juveniles in the commercial fishery. The estimates show that out of 31 finfish species observed, juveniles constituted an average of 50% of the catch (Radhakrishnan *et al.*, 2006).

Study had been made to quantify the amount of cephalopod juveniles landed on the east coast of India by Mohamad *et al.* (2009) who reported that for Sepia pharaonis, 6.9% (2281 t) of the catch was constituted by juveniles, but the proportion was very high (22.4%) along east coast.

Even though the researchers and fishermen in India have succeeded in improving the fishing with the help of technological advancements, huge amount of future income is being lost in the form of large quantity of juveniles being destroyed every year (Sathiadas *et al.*, 2005; Najmudeen and Sathiadas 2008; Kamei *et al.*, 2013). Long term benefits of mesh size shifts to larger sizes are very difficult for fishers to comprehend and accept. Indeed, even demonstrating the long term benefits and short-term losses doesn't make fishers convinced of the need for conservation and change (Mohamad *et al.*, 2009) as the field level extension work is poor and considerable awareness needs to be developed among fishers to move towards sustainable marine fisheries in India.

Though it is always said that it is better to remove a part of the catch from the aquatic ecosystem in order to allow other fishes to grow better and also maintain the food chain for the remaining stock. However, if the juveniles are wantonly destroyed, there will be a problem for recruitment in the future. In this line, the government has implemented monsoon fishing ban on mechanised fishing units along the coastal states. In the state of Maharashtra, the ban period is from 10th June to around 15th of August. Good fisheries management generally requires the fishing gears to retain large fish while allowing small juveniles to escape (Armstrong *et al.*, 1990). When fishermen realize that the catch contains higher percentage of juveniles, they should try to change the fishing ground and migrate to other places where abundance of adult is high.

Conclusion

A huge economic loss by fishing of juveniles of 18 commercially important species from the three selected landing centers was recorded. The highest economic loss was from Cuff Parade by IBM gillnetter followed by non motorised gillnetter operated from Mahim and OBM from Versova landing centre. Species wise maximum loss was observed by S. commerson, S. guttatus and R. kanagurta from OBM, IBM and non motorised gillnetters respectively. In OBM highest loss was observed in September, January in IBM and November in non-motorised gillnetters.

ACKNOWLEDGEMENTS

Authors wish to thank, Dr. W. S. Lakra, Director and Vice Chancellor, Central Institute of Fisheries Education, for providing the necessary facilities and guidance during the course of investigation.

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