Fisheries Management of a Small Shrimp Trawl in the Seto Inland Sea—Discarded Fishes and Mesh Size Regulation

TADASHI TOKAI* and TAKERU KITAHARA†
*Nansei National Fisheries Research Institute, Ohno-cho, Hiroshima, 739-04 Japan
†Tokyo University of Fisheries, Konan-cho, Minato-ku, Tokyo, 108 Japan

An enclosed coastal sea such as the Seto Inland Sea functions not only as nursery ground for juveniles of many species but also as fishing ground for trawl fisheries. A small shrimp trawl net has small-mesh codends. Consequently, in the small shrimp trawl fishery, lots of juvenile flounders smaller than a commercial size are caught and discarded at sea. It was found that the annual amount of juvenile finespotted flounder discarded at sea was about 200,000 in number(1 ton in weight) per a boat in the Seto Inland Sea. Most of these discarded juveniles are dead. The authors believe that the catching and discarding of these juveniles have a detrimental effect on fisheries of flounders in the future. The small trawl fishery also catches and discards at sea shrimp smaller than a commercial size, since the mesh size now used is too small. For the purpose of reducing the amount of discards at sea, we determined the mesh selectivity curves of the small shrimp trawl by Tokai and Kitahara's method. The authors propose, as an objective in managing the present small trawl fishery, that the amount of a few important target species discarded should be made as small as possible without a remarkable decrease in the landing of the commercial size fishes. Moreover, according to the objective the authors attempt to estimate appropriate mesh sizes for the shrimp fishery in the Seto Inland Sea. The result seems to be useful for predicting the amount of the target species discarded at sea, using a fishery model. This mesh size regulation is probably acceptable for the small trawl fishermen.

In the Seto Inland Sea, the annual landing of the small trawl fisheries has maintained approximately 100,000 tons for these twenty years. Small trawl fisheries exploit many small shrimps and depend greatly on them in the Seto Inland Sea. Southern rough shrimp Trachypenaeus curvirostris is the most important target species of small shrimps besides kuruma prawn Penaeuse japonicus. In 1987, Small shrimps registered landings of 20,040 tons or about 95 per cent of the total shrimp landings, in the small trawl fisheries of the Seto Inland. Sea(Statistics and Information Department of Chugoku-Shikoku Regional Agricultural Administration Office, 1989). In particular, a shrimp beam trawl fishery fished 74 % of this shrimp catch in the small trawl fisheries. At the same time, the main species of fishes concerned are finespotted flounder Pleuronichthys cornutus and marbled sole Limanda yokohamae etc., as well. The landing of flounders amounted to 7,532 tons in 1987. Moreover, mantis shrimp Oratosquilla oratoria also is an important target species in addition to shrimps and flounders in the small trawl fisheries.

Marine Pollution Bulletin, Vol. 23, pp. 305–310, 1991.
Printed in Great Britain
0025-326X/91 $3.00+0.00

Distributions of juvenile flounders

Distributions of two juvenile flounders, finespotted flounder and marbled sole, were investigated in small trawl fishing grounds by small trawl surveys in the Suo-Nada, western Seto Inland Sea (Tokai, 1989). In May juvenile marbled sole immigrated from the shallower inshore less than 10 m deep to the survey area. Juvenile finespotted flounders begun to settle at the area less than 30 m deep in February. Afterwards, marbled sole juveniles were widely distributed and abundant in this area during late spring and summer, and finespotted flounders juveniles from March to November, too (e.g., The distributions of two juvenile flounders in June are shown in Figure 1).

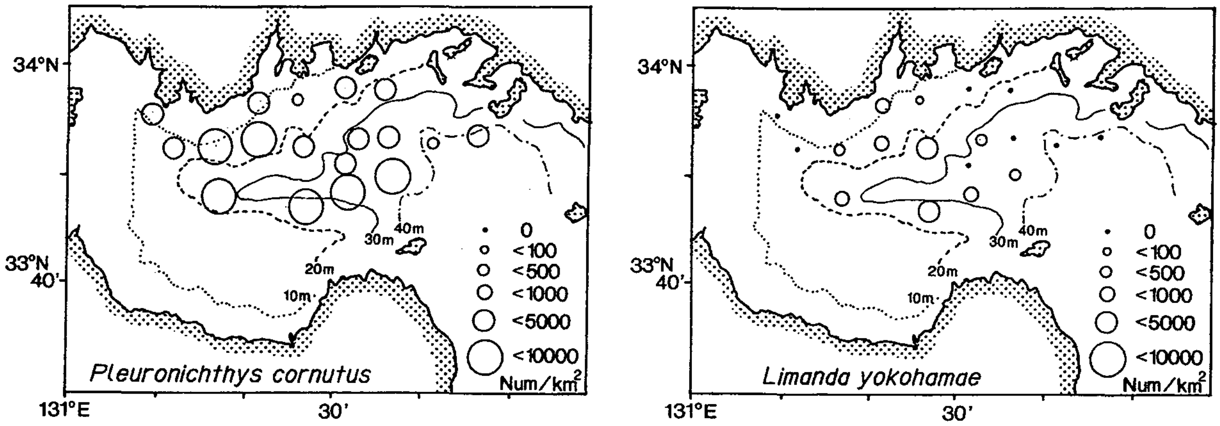

Fig. 1 Distributions (catch number per km²) of two juvenile flounders, finespotted flounder P. cornutus (left) and marbled sole L. yokohamae (right) in the Suo-Nada in June.

The most part of the Seto Inland Sea is shallower than 40 m in depth, which are fishing grounds of the small trawl fisheries. Accordingly, distributions of two juvenile flounders almost overlap small trawl fishing ground.

Juveniles discarded after catch and sort in small trawl fisheries

In the preceding section, juvenile flounders are distributed in the fishing grounds of the small trawl fisheries. In addition, the shrimp beam trawl net has small-mesh codends, about 16.5 - 25.1 mm in stretched measure, in the Seto Inland Sea since its main target species are shrimps. Consequently, lots of two juvenile flounders, finespotted flounder and marbled sole, are caught in the shrimp beam trawl fishery and most of them are usually discarded at sea (Tokai, 1989), because they are considerably smaller than commercial size, about 100 mm in body length. Discards of juvenile flounders occur more abundantly from spring to summer when they are widely distributed. The annual amounts of juvenile finespotted flounder and marbled sole discarded at sea were about 200,000 in number (1.12 ton in weight) and 42,000 in number(0.17 ton in weight) per a boat in the Suo-nada, respectively. The number of the small trawl fishing boats in the Suo-Nada is approximately 550 boats. We believe that the catching and discarding of these juveniles have a detrimental effect on flounders stocks in the future. The importance of the discard effect on fishery resources has so far been emphasized in many other commercial fisheries, especially in shrimp fisheries (e.g., Saila, 1983: Atkinson, 1984). Small shrimps and mantis shrimp under commercial sizes are also discarded from the trawls immediately after sorting out the large size in the Seto Inland Sea (Fukuda and Matumura, 1986). The biological impact of the dead fishes discarded on the overall food chain, ecosystem and environments has little been investigated. The dead fish discarded by the small trawl fishery such as juvenile flounders may, however, be regarded as the loading of organic matter to marine environment.

Determination of mesh selectivity curves of the shrimp beam trawl for the fisheries management

In order to reduce discarded fish and protect juvenile, there are several management measures, for example, the establishment of open or closed seasons, the establishment of open or closed areas and the regulation of mesh sizes in fishing nets etc. Since the fishing grounds and seasons of the small trawl fishery overlap the distributions of juvenile flounders, however, it is difficult to establish closed seasons and areas. Accordingly, we examine the mesh sizes regulation and attempt to estimate appropriate mesh sizes for the present shrimp fishery.

Studies of mesh selectivities are necessary for reducing the amount of discard at sea (Jean, 1963; Jones, 1976; Saila, 1983). The mesh selectivity curves of the shrimp beam trawl were determined for two shrimps, southern rough shrimp and mantis shrimp (Tokai et al., 1990). A covered-net fishing experiment was carried out of a shrimp beam trawl with codends of six mesh-sizes in the Suo-nada, on July 7 - 9, 1984. The mesh size of the used cover was 13.8 mm in stretched measure. The covernet of 13.8 mm mesh size had no effect on number, weight and size distribution of catch in codend in this fishing experiment. The respective mesh selectivities of 16.5, 19.9, 22.1 and 25.1 mm mesh sizes are determined for the two shrimps every length class(Fig. 2). Here, the mesh selectivities of 46.1 and 69.3 mm mesh sizes were almost 0. In Fig. 2, the selectivities of each mesh sizes increase with length in certain length ranges.

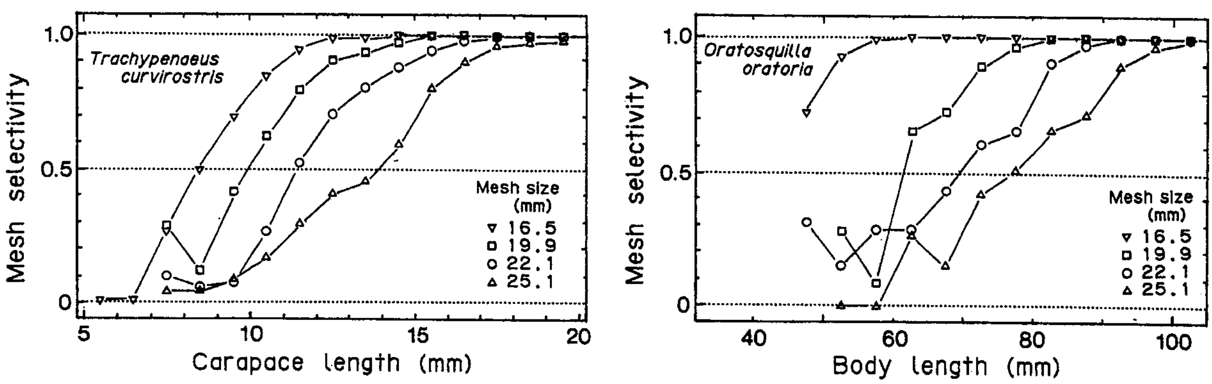

Fig. 2 The mesh selectivities of 16.5, 19.9, 22.1 and 25.1 mm mesh codends for southern rough shrimp T. curvirostris and mantis shrimp O. oratoria plotted against length.

Using (m_o, l_o) = (-8.16, -4.60) for southern rough shrimp, and (3.65, 5.07) for mantis shrimp through method of determining mesh selectivity curve (Tokai and Kitahara, 1989), we plot the mesh selectivities against $R = (l - l_o)/(m - m_o)$ in Fig. 3. Applying the cubic spline function (Ichida and Yoshimoto, 1979) to these plots, the respective master curves of the mesh selectivity were estimated for southern rough shrimp and mantis shrimp as follows:

$$S(R) = \begin{cases} -.5004 + 4.791R - 16.41R^2 + 19.73R^3 & \text{for } .304 \le R < .460, \\ 35.62 - 210.8R + 408.9R^2 - 257.1R^3 & \text{for } .460 \le R < .586, \\ -14.38 + 59.34R - 76.30R^2 + 32.68R^3 & \text{for } .586 \le R \le .845, \end{cases} \quad (1)$$

$$S(R) = \begin{cases} -.09189 + .1677R - .09515R^2 + .03514R^3 & \text{for } 1.05 \le R < 3.34, \\ -13.90 + 9.768R - 2.132R^2 + .1548R^3 & \text{for } 3.34 \le R \le 4.39. \end{cases} \quad (2)$$

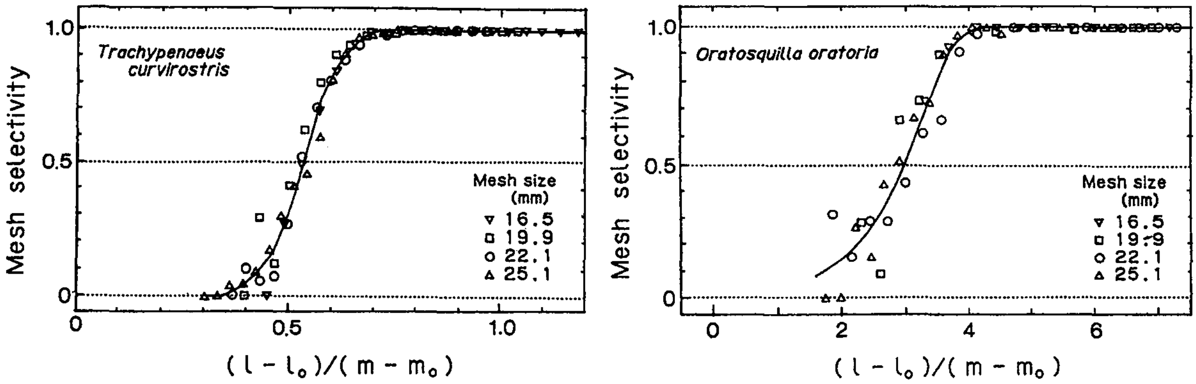

Fig. 3 The mesh selectivities of 16.5, 19.9, 22.1 and 25.1 mm mesh codends for southern rough shrimp T. curvirostris and mantis shrimp O. oratoria plotted against $(l-l_o)/(m-m_o)$. Solid line shows master curve.

The master curves can give the mesh selectivity curves of a specified mesh size for the two shrimps. In the same fishing experiment, the mesh selectivity curves for finespotted flounder and marbled sole were also determined (Tokai et al., 1989).

Determination of the appropriate mesh sizes

Before going further, we define the culling selectivity and total selectivity. Jean (1963) called it "cull" that fishermen choose landings of commercial value from catch on board. We define the culling selectivity as the ratio of landing number to catch number(= landing no. + discard no.) at each length class. Conversely landing can be given by the production of catch and culling selectivity, while catch can be obtained through the process of mesh selectivity. The total selectivity is defined as multiplying mesh selectivity and culling one together.

In estimating appropriate mesh sizes in a fishery, we must naturally have objectives for managements of that fishery. The authors (unpublished) propose the objective for fishery management that the amount of a few target species discarded is made as small as possible, without a remarkable decrease in the landing of the target species. Moreover, We present that this objective can be attained by adopting a mesh size whose mesh selectivity curve is the most similar to the patterns of total selectivities for the target species.

Fukuda and Matumura (1986) collected the data on the landing and discard of southern rough shrimp and mantis shrimp caught in a small trawl fishery off the eastern region of Okayama Pref. The codend of 25.1 mm mesh size was usually used in this small trawl fishery. From their data, we estimate the culling selectivities for the two shrimps. The total selectivities for southern rough shrimp and mantis shrimp are estimated as a function of body length (Fig. 4).

In general the total selectivity steeply increases with length. For example, the total selectivity for southern rough shrimp begins to increase from the length class of 40 - 45 mm and steeply increases with length, and then reaches 1 at the length class of 80 - 85 mm (solid circle in Fig. 4). On the other hand, the total selectivity for mantis shrimp starts to increase from the length class of 85 - 90 mm and steeply increases with length, and then reaches 1 at length of 110 mm or more (solid circle in Fig. 4). In fact, however, the fishery catches lots of the southern rough shrimp less than 40 mm in length and mantis shrimp less than 80 mm.

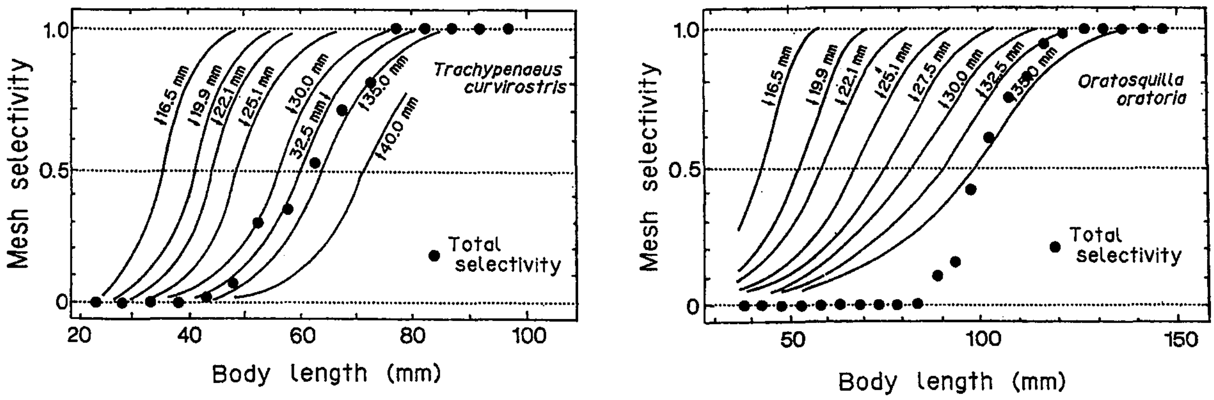

Fig. 4 The total selectivities and the determined mesh selectivity curves plotted against body length for southern rough shrimp T. curvirostris and mantis shrimp O. oratoria plotted against length. Solid circles indicate the total selectivities. Solid lines and numbers in figures show the determined mesh selectivity curves and mesh sizes, respectively.

Fig. 4 also presents the mesh selectivity curves of several mesh sizes calculated from Eqs. (1) and (2) as a function of body length. In calculating the above curves, since l in Eq. (1) for southern rough shrimp is carapace length, carapace length l_c (in mm) was converted into body length l_b (in mm) by the following relation:

$$l_b = 11.02 + 2.871 l_c \quad \text{(correlation coefficient r = 0.976).}$$

This figure indicates that the total selectivity roughly agrees with the mesh selectivity curve of 32.5mm mesh size for southern rough shrimp. An comparison of the total selectivity with the curves gives 32.5 or 35.0 mm for mantis shrimp. Thus the mesh used at present (25.1 mm) is too large for southern rough shrimp as well as for mantis shrimp. Since southern rough shrimp is smallest target species, we determine 32.5 mm mesh size as an appropriate mesh size in the current small trawl fishery off Okayama Pref.

We predict the amount of the target species discarded at sea, using a fishery model. The fishery model is built on the following assumptions. No change of recruit, no effect of density on stocks, fish through trawl mesh returning to stocks without any damage, the complete death of all discarded fish and no change of fishery conditions besides an increase in mesh size. The adoption of 32.5 mm mesh size will make southern rough shrimp discards almost nothing, while the amount of landing shows an increase of 17% without an immediate decline, as compared with the one of the present fishery. The amount of discard of mantis shrimp will decrease to 54% and that of landing shows an increase of 24 % without an immediate decrease.

In general, the use of a larger-mesh codend probably offers the follow-

This paper discusses the results of trawl surveys conducted in 1982 to 1988. The production data included the 1958 total production.

Methodology

The trawl, being a non-selective gear, was ideal for determining the degree of exploitation of Manila Bay fisheries. Fishing observations were conducted on board a 7.31 GT, 100-hp medium trawler for the duration of the survey. The boat had a measurement of 11.5 x 1.5 meters. The headrope was measured at 22 meters and the cod end was 2 centimeters.

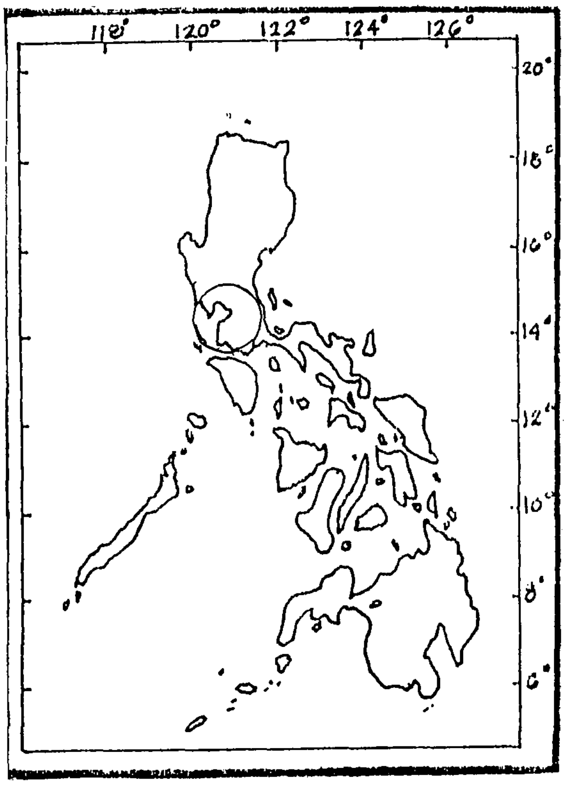

Figure 1. Philippine map showing Manila Bay.

The total catches were recorded for every fishing operation. Fishes and invertebrates were identified up to species level.

The total weight was recorded in kilograms. The CPUE values were computed from the catch data and fishing time, expressed in kg/hr.

The density of active fishing effort was conducted by counting the number of boats in a given transect. This was done by travelling in a straight line in a banca across the sampling area (transect) and counting all the fishing boats on both sides, then calculating boat densities from the distance covered and transect width.

Major species were collected. The total length of the fishes were measured in centimeters. However, the midlength was used in computing the average mean length of major species from the trawl catch.

The MSY and fMSY were computed using the Fox and Schaefer models for surplus production.

Result and Discussion

There was a fluctuation of the annual fish production of Manila Bay in 1982. The production decreased from about 45,952 mt to 41,352 mt in 1983. There was, however, an erratic increase and decrease in the succeeding years. The increase was attibuted to the introduction of high opening trawlers which proved efficient in catching the pelagic species which have become the dominant fish group.

The CPUE values of trawl operations conducted in the Bay showed a maximum value of 88 kg/hr in 1986 while there was a decrease in the next two years at 40 kg/hr and 29 kg/hr, respectively. The number of trawlers operating in the Bay affected the CPUE value of each fishing operation. The CPUE value in 1986 was the average of 702 units while an increase to 750 and 802 units in the next two years decreased the CPUE values.

Fishes from heavily exploited areas have average sizes that become reduced. Length-frequency data in 1982 to 1988 showed a decrease of the mean length of major species. Mean length of samples of Sardinella fimbriata decreased from 15 to 9 cm; Nemipterus japonicus, 17 cm to 12 cm; Leiognathus insidiator, 9 cm to 6 cm; Trichiurus lepturus,38.5 cm to 27 cm; Rastrelliger bracysoma, 12 cm to 9 cm; and Stolephorus commersoni, 5.5 cm to 2 cm.

There had also been a change in the fish population of the Bay. The volume of desirable species had diminished considerably. It is known that when a group of fish disappears, other species take over to replace it. There is a general shift in species composition with increased fishing intensity. Today, the trawl catch in Manila Bay is dominated by pelagic species rather than the demersal species. Furthermore, the increase of the percentage composition of the invertebrate group was due to the decrease of the predator group that feeds on eggs and larvae of the invertebrates. There was also a minimal percentage of trashfish composition due to the gradual acceptability of some species (Apogon spp.) of trashfish as foodfish.

There were about 48 species listed in the trawl catch composition in 1982. In the next year, about 52 species were listed. In the succeeding years up to 1988, an average of only 12 species composed the trawl catch. There is an apparent reduction of the number of species per trawling operation. This is perceived as an indication of heavy exploitation which is common in many overfished coastal areas of the country.

An actual boat density count showed that Manila Bay has an average of 14 boats per square kilometer. A majority of the fishing gears were trawlers, gill netters and push netters. The area at the eastern side of the Bay was the most dense at 21 boats per square kilometer while least dense was at the western side at 12 boats per square kilometer. Trawlers had the highest count among the fishing boats recorded at 42%. Other gears observed were push netters (33%) and gillnetters (25%). The eastern and the northeastern sides of the Bay are trawlable areas. The western and the northwestern sides have the shallowest portions of the Bay where push netters are known to operate all over the Bay.

The relationship between the fishing effort and the annual production was used to calculate the maximum sustainable yield (MSY) and MSY effort (fMSY). Figure 2 shows the MSY values of Manila Bay at about 11,500 to 13,500 mt. These yields will require an effort of 772 units of trawlers for the whole year. It is also shown that for Manila Bay to be able to sustain its fisheries, the fishing effort must be reduced to one third of the present effort exerted into the Bay.

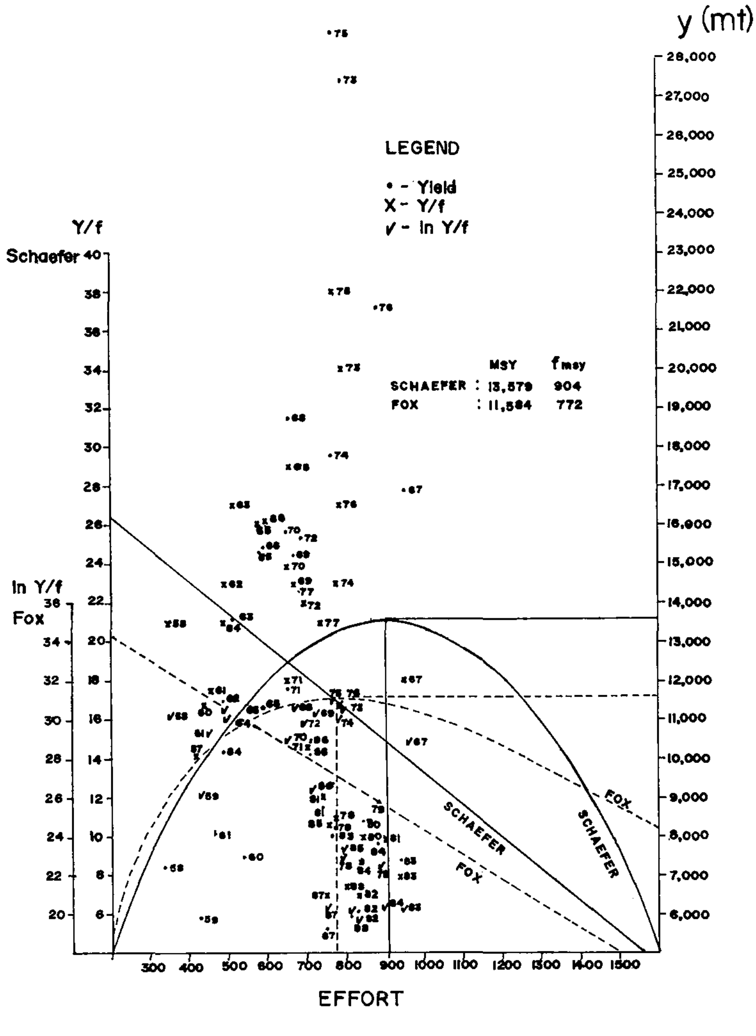

Figure 2. The relationship of yield and effort, and CPUE of total production in Manila Bay in 1958 to 1988.

While several commercial gears are not allowed to operate inside the Bay to allow the various fisheries to recover, the use of destructive fishing methods, such as the use of fine-meshed nets, the use of dynamite and cyanide and electro-fishing must be discouraged. This is to give chance for smaller fishes to grow. Selective fishing gears such as gillnet, bottom set long line and hook and line must be sustained.

Manila Bay lacks a comprehensive management plan formulated to protect, conserve and revive its fishery resources. Management measures which are being implemented in the Bay are not concerted and are protracted. The Government and the private sector, however, are doing their best effort to manage the fishery resources of the Bay. Recently, non-government organizations have taken active roles in exploring different avenues for a workable comprehensive management scheme for Manila Bay. Furthermore, the Fishery Sector Program (FSP) funded by the Asian Development Bank (ADB) had identified Manila Bay as one of the priority bays to be studied. The program is composed of six components, namely: resource and ecological assessments, coastal resource management, research and extension, infrastructure, law enforcement and credit. The objective is to alleviate the worsening social, economic and political conditions in the coastal areas.

Manila Bay, just like any other fishing ground in the Philippines is covered by Fisheries Act 704. This Act embodies laws which aim to protect, conserve and manage the country's fisheries and aquatic resources. However, some of these laws need revisions to cope up with changing times. A new Fisheries Code is now being consolidated and reviewed by lawmakers. This code aims to offer possible solutions to present problems and issues that is faced by the country's fisheries and other aquatic resources. Some of the measures which could be considered are the following: (1) increase of mesh size of nets from 3 cm to 4 or 5 cm; (2) municipalities should limit the issuance of trawl licenses; and (3) motorized push netters should notbe allowed to operate in shallower areas.

References

Fox, P.J. (1986). A manual of rapid appraisal for Philippine coastal fisheries. pp. 43

Ronquillo, I.A. (1989). Experience in fisheries management in the Philippines. (Manuscript). pp. 35

Silvestre, G.R., R. Federizon, J.C. Munoz and D. Pauly. (1987). Overexploitation of the demersal resources of Manila Bay. RAPA Report: 1987/10. pp. 267-287.

Sparre, P. (1985). Introduction to tropical fish stock assessment. GCP/INT/392/DEN. pp.262-264.

Tiews, K. (1958). Report to the Government of the Philippines on marine fishery resources. Philippine Journal of Fisheries. 6(2): pp. 107-209.