Maximum Sustainable Yield Assessment in Thailand:
A Case of Pelagic Fish in the Andaman Sea

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Abstract

Since 2015, fisheries management scheme in Thailand has been shifted from open access fishery to limited access fishery aiming to reorganize fisheries in and outside Thai waters with the views to prevent IUU fishing and to preserve aquatic animal resources as a sustainable source of food for humanity. Based on the Royal Ordinance on Fisheries B.E. 2558 (2019), fishing license is issued based on reference point. Currently, maximum sustainable yield (MSY) is used as the reference point for fishing license issuance. The MSY assessment is conducted every year with three groups of species, i.e. demersal fish, pelagic fish, and anchovy, due to the complexity of tropical multi-species fishery. Then, the total allowable catch (TAC) is determined based on the MSY assessment results. The TAC will be allocated to every single vessel both artisanal and commercial fishing vessels and an amount of TAC is specified in commercial fishing licenses.

MSY assessment of pelagic fish includes several pelagic species, e.g. mackerels, sardines, and scads, as well as neritic tunas. Fox surplus production model is used for the assessment. Catch and fishing effort data between 1998 and 2018 was used for the MSY assessment of pelagic fish in the Andaman Sea in 2019. Thai purse seine was used as the standard fishing gear. The results revealed that the MSY was 118,467 tons at the fishing effort (F_{msy}) of 68,545 days. While, the catch in 2018 was 119,557 tons with the fishing effort of 45,957 days. In the Andaman Sea, the pelagic resources are now being fished at a fishing effort level commensurate with the F_{msy}.

In addition, Thompson and Bell model was used to monitor the status of some single pelagic species. Length frequency data of three selected species, i.e., *Rastrelliger brachysoma*; short mackerel, *R. kanagurta*; Indian mackerel, and *Sardinella gibbosa*; goldstripe sardinella in 2018 were used with the model. The results disclosed that F-factor were 1.4, 0.6, and 1.5 respectively indicating that current fishing effort of short mackerel and goldstripe sardinella were lower than its fishing effort level which could produce MSY (F_{msy}) by 40% and 50% respectively while current fishing effort of Indian mackerel was over its F_{msy} by 40%. However, length frequency data of neritic tunas were not used with the model due to they are transboundary species and length data obtained was considered not covering the whole stock.

Key words: maximum sustainable yield, pelagic fish, Andaman Sea, Thailand

1. Introduction

Prior to 2015, marine fisheries in Thailand was characterized by an open access fishery. Fishing right was widely open for those who wish to pursue a fishing career resulting in continuous increase in number of fishing vessels particularly during 1962 – 1991. Although, fishing licenses for trawls and anchovy fishing gear, i.e., anchovy purse seine, anchovy lift net, and anchovy falling net, had been limited since 1996 and 2000 respectively, fishing effort, e.g., number of fishing day, had not been controlled. Consequently, overfishing was occurred causing degradation of fisheries resources which could be observed by reduction of catch per unit effort (CPUE) and so-called growth overfishing.

In November 2015, three important documents related to fisheries management, i.e. the Royal Ordinance on Fisheries 2015, the Marine Fisheries Management Plan (FMP) 2015 – 2019, and the National Plan of Action to Prevent, Deter, and Eliminate Illegal, Unreported, and Unregulated Fishing (NPOA – IUU), have been approved by the Thai Cabinet. Fundamental of these documents is the transformation of Thai fisheries management scheme from the open access fishery to a limited access fishery. Their substantial principles are to establish a system of good governance in order to ensure sustainable use of fisheries resources as determined by the examination of best scientific evidence and to establish an approach to the issuance of fishing licenses in line with the fishing capacity and the maximum sustainable yield by using reference points as the basis for determination. It has been the most important change in the management of Thai marine fisheries.

Since 2015, maximum sustainable yield (MSY) has been used as the reference point for fishing license issuance. Number of fishing days for each kind of fishing gear will be determined based on MSY. Furthermore, the result of MSY assessment is submitted to the National Committee on Fisheries Policy every year and the total allowable catch (TAC) is approved by the Committee every two years. Then, the TAC will be allocated to each single fishing vessels both artisanal and commercial vessels and specified in the commercial fishing licenses. Although, the catch of each vessel is currently not controlled, number of fishing days is controlled instead in order to control the catch in line with allocated catch and to control fishing effort not exceed the fishing effort that can produce MSY (F_{msy}). The fishing days of highly efficient fishing gear, i.e., all kinds of trawl, purse seine, anchovy purse seine, and anchovy falling/lifting net, is limited.

This paper described models used for MSY assessment in Thai waters with a case of pelagic fish in the Andaman Sea. Two models were used to assess the status of pelagic fish. Fox surplus production model was used for the group of pelagic fish assessment and the result was used as the reference point for fishing license issuance. In addition, length-based Thompson and Bell Model was used to assess the status of some selected pelagic species.

2. Methods

MSY in Thai waters is estimated for three groups of species, i.e., demersal fish, anchovy, and pelagic fish, by using the Fox surplus production model (Fox, 1970). Fox model is a holistic surplus production model. Under equilibrium condition, biomass declines if the fishing effort increase. Since catch per unit effort (CPUE) can be proportional to biomass, effort and CPUE will have negative correlation. In Fox model, the relationship between CPUE and effort is assumed as;

$$\ln CPUE_i = c + dE_i$$

where $CPUE_i$ is catch per unit effort in year i,

E_i is fishing effort in year i, and

c, d are regression coefficients.

Since yield can be calculated as $CPUE_i \times E_i$, maximum sustainable yield (MSY) and fishing effort for the MSY (F_{msy}) can be calculated, once c and d are estimated from CPUE and effort data as the equations below;

$$MSY = -\left(\frac{1}{d}\right) e^{c-1}$$

$$F_{msy} = -\left(\frac{1}{d}\right)$$

In addition to Fox model which is used for estimation of reference point for fishing license issuance, length-based Thompson and Bell model is used for monitoring status of some selected pelagic species. Thompson and Bell model (1934) is a predictive model, which predicts the effect of the changes in fishing effort by calculating the population and biomass of a cohort numerically.

The age-based Thompson and Bell model is very similar to yield per recruit (YPR) model (Beverton and Holt, 1957). The difference is that YPR model uses von Bertalanffy's growth curve and integration while Thompson and Bell model is more flexible on the growth and using numerical calculation by years.

For utilizing length frequency data, Thompson and Bell expanded the model to length-based model. For converting age to length, growth is assumed by von Bertalanffy's growth curve. Several calculations were conducted in order to observe the changes of fishing effort by multiplying F-factor to the current fishing mortality. From the result, this analysis predicts MSY and F-factor for MSY. The equations are as follows;

$$Z_i = M + X * F_i$$

$$N(L_{i+1}) = N(L_i) * \frac{\frac{1}{H_i} - \frac{XF_i}{Z_i}}{H_i - \frac{XF_i}{Z_i}}$$

$$H_i = \left[\frac{L_\infty - L_i}{L_\infty - L_{i+1}}\right]^{\frac{M}{2K}}$$

$$C_i = [N(L_i) - N(L_{i+1})]\frac{XF_i}{Z_i}$$

$$\overline{w}_i = q\left[\frac{L_i + L_{i+1}}{2}\right]^b$$

$$Y_i = C_i \cdot \overline{w}_i$$

$$Y = \sum C_i \cdot \overline{w}_i$$

where Z_i is total mortality in the length class *i*,

M is natural mortality,

X is F-factor,

F_i is current fishing mortality in length class *i*,

H_i is natural mortality factor in length class *i*, calculated from natural mortality *M* and the parameters of von Bertalanffy's growth curve L_∞ and *K*,

C_i is predicted catch in number in the length class *i*, and

$\overline{w}_i$ is average weight of the fish in the length class *i*, calculated from parameters of length-weight relationship *a* and *b*.

Finally, the yield for length class *i* is calculated by C_i and $\overline{w}_i$ and total predicted yield *Y* can be calculated by the summation of Y_i, which is a function of F-factor *X*. Changing *X*, maximum yield *Y* can be found which is MSY, and the *X* providing MSY is the relative effort for MSY comparing to the current fishing effort.

3. Result and discussion

3.1 Fox model

Catch of pelagic fish, including mackerels, sardines, scads, trevallies, and neritic tunas, from purse seine and gill net in 1998 and 2018 was used for the MSY assessment of pelagic fish in the Andaman Sea in 2019. Thai purse seine was used as the standard fishing gear. The results revealed that the MSY was 118,467 tons at the fishing effort (F_{msy}) of 68,545 days. While, the catch in 2018 was 119,557 tons with the fishing effort of 45,957 days. In the Andaman Sea, the pelagic resources are now being fished at a fishing effort level commensurate with the F_{msy} (Figure 1).

The catch of pelagic fish in the Andaman Sea in 2018 was slightly higher than its MSY. This was due to the implementation of fishing day scheme instead of catch control. Once MSY assessment is finalized, total allowable catch (TAC) is determined based on MSY. In 2018 – 2019, TAC was set at 93% MSY. TAC is then allocated to artisanal fishing vessels, commercial fishing vessels operating low efficient fishing gear, i.e., gill net, and commercial fishing vessels operating highly efficient fishing gear, i.e., purse seine. The number of fishing days of purse seiners is determined by using CPUEs of different vessel sizes multiplied by various numbers of fishing day. The result of this step is estimated catch by vessels. The maximum number of fishing days, which the total estimated catch from all vessels does not exceed the TAC, is given to purse seiners. In 2018 – 2019, the number of fishing day for purse seiners is 255 days/year.

In 2018, CPUEs for catch allocation ranged from 1,088 – 1,832 kg/day which was based on a study in 2015 and varied by vessel sizes of 10 – 150 gross tonnage. However, the average actual CPUE of purse seiners in 2018 was 2,602 kg/day. The sharp increase in CPUE resulted from implementation of several management measures which have been implemented since 2015. The fishing day scheme has been introduced in 2015 in order to stop overfishing in Thai waters and control fishing effort not exceed the level that can produce MSY. In addition, standard of fishing gear has been implemented in order to control the efficiency of fishing gear, i.e., limitation of length or number of fishing gear. The seasonal area closure in the Andaman Sea during 1 April to 30 June every year has also been implemented successfully. As a result, the catch of pelagic fish in the Andaman Sea in 2018 was 1,090 tons higher than MSY or 0.92% higher than MSY while the fishing effort was 22,588 days lower than F_{msy} or 49.15% lower than F_{msy}.

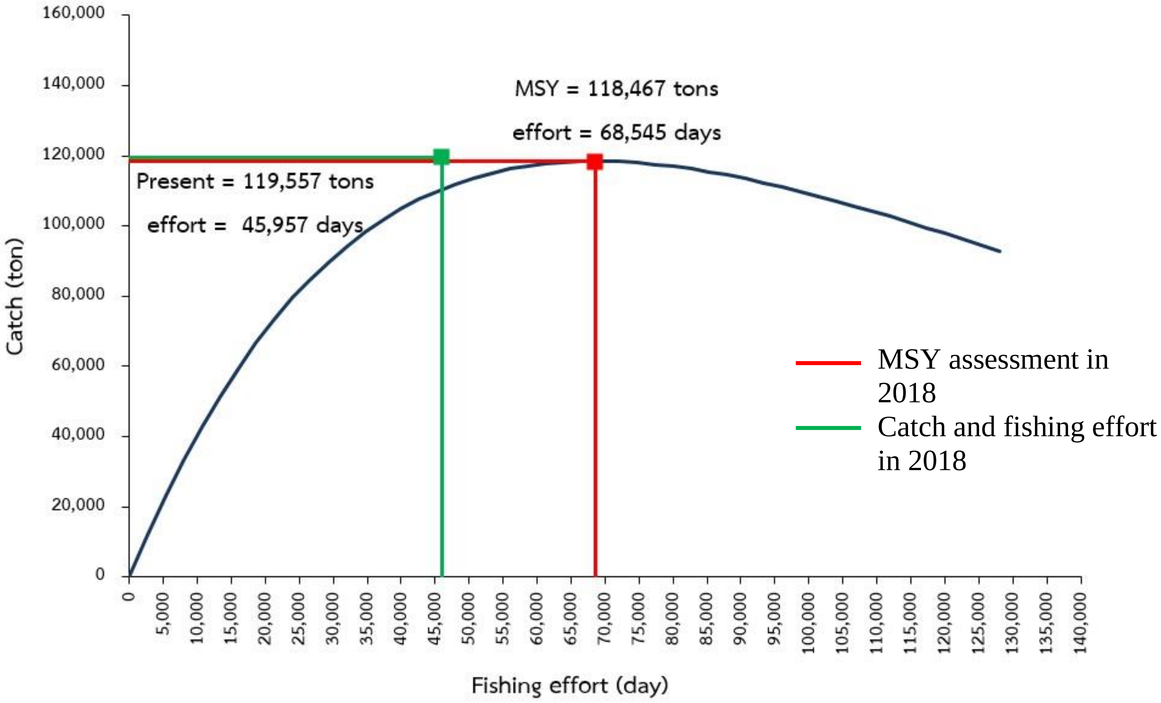

Figure 1 Maximum sustainable yield and fishing effort assessment of pelagic fish in the Andaman Sea, 2019 by using Fox surplus production model

3.2 Thompson and Bell model

Three species, i.e., *Rastrelliger brachysoma*; short mackerel, *R. kanagurta*; Indian mackerel, and *Sardinella gibbosa*; goldstripe sardinella, were selected to assess single-species MSY. Length frequency data of selected species were collected from purse seine every month during January – December 2018. However, length frequency data of neritic tunas were not used with the model due to they are transboundary species and length data obtained was considered not covering the whole stock.

The results disclosed that F-factor were 1.4, 0.6, and 1.5 respectively indicating that current fishing effort of short mackerel and goldstripe sardinella were lower than its fishing effort level that can produce MSY (F_{msy}) by 40% and 50% respectively while current fishing effort of Indian mackerel was over its F_{msy} by 40% (Table 1).

Table 1 Maximum sustainable yield of some pelagic species in the Andaman Sea in 2019 by using length-based Thompson and Bell model

Scientific name	Common name	MSY (ton)	Catch in 2018 (ton)	F-factor	Status of fishing effort
Rastrelliger brachysoma	Short mackerel	9,137.6	9,013.32	1.4	40% under MSY
R. kanagurta	Indian mackerel	21,995.3	20,735.86	0.6	40% over MSY
Sardinella gibbosa	Goldstripe sardinella	7,526.7	7,427.06	1.5	50% under MSY

One challenge in fisheries management in tropical is multi-species fisheries. Most of fishing gear can be used to catch several species in the same operation. In case of purse seine in Thai waters, there are more than 200 species recorded in catch data, although three fourths of the catch contain about 10 species. In the multi-species fisheries situation, input or output control of a specific species is sometimes unrealistic because the stop for a specific species fishery means the stop for the multi-species fisheries, which affects the catch of the other species. Thus, for tropical multi-species fisheries, management of every single species within sustainable level at the same time is extremely unlikely. Therefore, several management approaches including input, output, and technical controls could together be implemented in the fisheries management in tropical zones.

4. Conclusion

Fox surplus production model was used to estimate the pelagic fish MSY. In the Andaman Sea, the pelagic fish resources are now being fished at a level commensurate with the MSY. The fishing effort was well controlled under F_{msy}, although the catch in 2018 was a little higher than MSY. While, length-based Thompson and Bell model was used to estimate MSY of some pelagic species. The results revealed that current fishing effort of short mackerel and goldstripe sardinella were lower than its F_{msy} by 40% and 50% respectively while current fishing effort of Indian mackerel was over its F_{msy} by 40%.

5. References

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