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Growth, Population Dynamics and Optimum Yield of Indian Mackerel, *Rastrelliger kanagurta* (Cuvier, 1816), in the Eastern Gulf of Thailand

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Thailand's marine fisheries have been intensively developed since 1950s. Catches are comprised of the pelagic and demesal fishes as well as other aquatic animals. Among the pelagic species, Indian mackerel *Rastrelliger kanagurta* (Cuvier, 1816) is one of species that has created significant economic value in the country. Meanwhile the precise information on population dynamics, stock assessment and optimum yield of *R. kanagurta* were still rare, especially in the Eastern-Gulf of Thailand. The objectives of this study was to estimate the growth and mortality rates to optimize the fishing pressure of the stock of the Indian mackerel in the Eastern-GoT, base on an otolith approach. In this study, the age-based approach of growth and mortality estimation and the relative yield per recruit were analyzed using the FiSAT II software. For the results, the growth parameters of von Bertalanffy growth model were K=4.24 $year^{-1}$ and L_∞ = 214.37 millimeters, respectively. The total mortality coefficient (*Z*) was estimated at 6.09 $year^{-1}$ and the natural mortality coefficient (*M*) was estimated as 2.70 $year^{-1}$. The current fishing mortality (*F*) was calculated as 3.39 $year^{-1}$ and the actual value of exploitation rate (*E*) = 0.56. The relative yield per recruit was estimated from the knife-edge selection of size at first capture yielded the E_{max} and $E_{0.5}$ values at 0.49 and 0.32 respectively and the actual value of exploitation rate was higher than both E_{max} and the $E_{0.5}$, implying the overfishing situation of the stock. The possible fisheries management regime for this situation is increase size at first capture (L_c) and decrease fishing pressure, i.e. *E*-value. From this study, the length at first capture (L_c) between 150.06 and 214.37 millimeters and the 0.50 optimum level of exploitation (*E*) were recommended. For conclusion, this study illustrated the information on population dynamics and stock assessment of the *R. kanagurta* resources in the Eastern-GoT, as well the way forward for optimum exploitation. These findings can be further applied in the sustainability of Indian mackerel in the Eastern-GoT

Keywords: Fish stock assessment, mackerel, otolith, age and growth, mortality

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Introduction

The Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1816), is the tropical pelagic fish that commonly found in the Indian and the West Pacific Oceans and widespread in Southeastern Asia, in particular the Gulf of Thailand (GoT) (Luther, 1995; Khrueniam, *et al.*, 2013; Amin, *et al.*, 2014; Thongsila, *et al.*, 2012). This fish species is among the commercially important marine fishes and supports economically throughout its distribution range as well as considered as the common seafood for people (Khrueniam, *et al.*, 2013; Amin, *et al.*, 2014; Thongsila, *et al.*, 2012). The fisheries on *R. kanagurta* in the GoT have been developed since 1950s (Marine Fishery Laboratory, 1965). It is, then, become the main target species, in which, the highest yield of *R. kanagurta* from the Gulf of Thailand was found in 1994 at 50,898 metric tons, compared to 30,790 metric tons in 2014 (Fishery Statistics Analysis and Research Group, 2016). The yield of *R. kanagurta* between 1984 and 2009 in the GoT was found continously decressed (Koolkalaya *et al.*, 2015) which consequence by the concerns on stock status and the quantifying of optimum fishing intensity that should be recommended to sustain the resource.

The population parameters of the interesting fish stock, such as growth and mortality must be known to quantify the optimum fishing intensity, because they are the input parameters for the number of the stock assessment models. There are two main methods for determining fish growth i.e. direct and indirect methods. Among the direct methods, counting the otolith's ring was common for ageing and long been shown to provide a good approach for reconstructing the growth of fishes because of the constancy increment pattern during otolith growth, which can be related to fish age and fish length (Wilson and Larkin, 1980; Campana and Neilson, 1985; Morales-Nin, 1992; Chambers and Miller, 1995). In addition, since the daily increment technique of otolith was developed in the early 1970's, this technique has gained wide acceptance (Jones, 1992).

Growth data and the mathematical description of growth of fish are important informations for the field of fish stock assessment and fisheries management (Morales-Nin, 2000; Mehanna, 2001; Cadima, 2003; Lombarte *et al.,* 2003). The growth parameters obtain from fitting the observed growth data into the mathematical models are the basic data into the analytical models used in assessing and managing the status of the exploited fish stocks (Mehanna, 2001). Other than growth, the rate of mortality, which is cause of change in abundance of fish in any defined population, is also needed for the analytical stock assessment models, in which most of the mortality estimation models are also required growth parameters as the inputs. This study, therefore, firstly aims to examine growth parameters based on the otolith studies. The obtained growth parameters, then, further used for estimation of mortality rates and examining the optimum length at first capture and fishing pressure of *R. kanagurta* in the Eastern-GoT for further recommendation to the wise-use of the resource.

Materials and methods

Fish sampling and otolith preparation

The samples of *R. kanagurta* were collected from the fish landing sites along the Eastern Gulf of Thailand (Fig. 1). Total length, body weight and sex of 103 individuals were recorded and the sample size distribution was showed in Figure 2. The pair of otolith (i.e. sagitta) from individual sample was extracted. Each sagitta was rinsed with water, cleaned from adhering tissue, dried and stored in plastic micro-centrifuge tubes. Then, each sagitta was embedded in epoxy resin. Each embedded sagitta was cut through the mid-plane, i.e. a transverse section, by using a slow-speed diamond wheel saw (SBT650, South Bay Technology), which continuously lubricated with coolant solution. The sections were polished down using silicon carbide paper (P2000 to P2500), rinsed with distillate water, until primodium was found. The right sagitta of each individual sample was used for ageing, meanwhile the left one was kept as spare if the right sagittal was broken or unreadable.

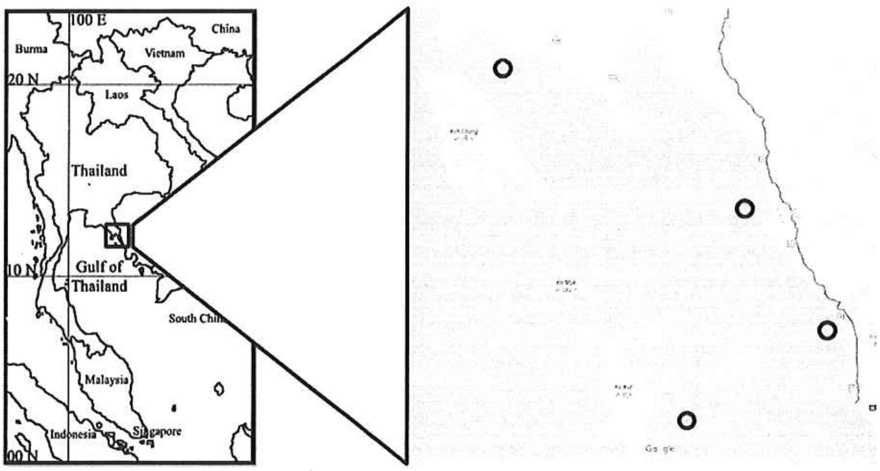

Figure 1. Collectted locations (○) of *Rastrelliger kanagurta* in the Eastern Gulf of Thailand

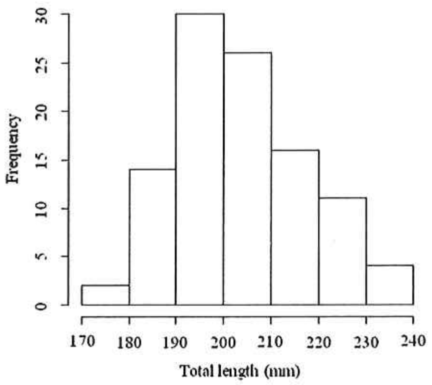

Figure 2. Sample's size distribution of *Rastrelliger kanagurta* from the Eastern Gulf of Thailand

Fish ageing

The sagitta sections (in total 103 samples, Fig. 2) were observed through a compound microscope at ×4, ×10 and ×40 magnification. At the highest magnification, the sagitta was taken photograph with a digital camera (ZEISS, AxioCam ERc 5s). The captured image was then used for daily ring count by using ImageJ program (Rasband, 2016). The age (days) of the individual fish ($\hat{T}$) was, then, estimated by the following equations

$$log_e\left(\frac{dl}{dt}\right) = \alpha - \beta l + \varepsilon, \text{ and}$$

$$\hat{T} = (e^{\alpha}\beta)^{-1}(e^{\beta L} - 1),$$

where, *dl* is the distance along the counting area, *dt* is the number of daily ring between the distance between counting area, *l* is the distance from otolith core to mid sampling area, *L* is the total distance from core to edge, α and β are the coefficients of the regression equation (Morales-Nin, 1992).

Age and growth analysis

The length-at-age dataset of *R. kanagurta*, from otolith reading, was fitted by using non-linear least-squares to estimate the growth parameters *viz.*, the asymptotic length (L_∞), and the growth coefficient (*K*). Then, the growth equation of *R. kanagurta* was presented by the von Bertalanffy's growth function (VBGF; Bertalanffy, 1938).

$$L_t = L_\infty\left(1 - e^{K(t-t_0)}\right),$$

where, L_t is the length at time t. t_0 is the age when the fish would have had length zero.

The growth performance index (ø'), a species-specific parameter to indicate the unreliability in the accuracy of estimated growth parameters was calculated with function as,

$$ø' = \log_{10}(K) + 2\cdot\log_{10}(L_\infty).$$

Mortallity, exploitation rates and relative yield perrecruit analysis

The total mortality rate (Z) was calculated by Hoenig' formula (Hoenig, 1982) as,

$$Z = \frac{1}{\left(c_1 \times (T_{max} - T_c)\right)}$$

where; t_{max} is the maximum age in years, t_c is mean age at first capture and c_1 is a function of the sample size from which t_{max} was estimated (pre-programmed in FiSAT II (Gayanilo *et al.*, 1996)).

Natural mortality rate (M) from Pauly's empirical formula (Pauly, 1980) which incoporated the growth parameters and taken mean temperature into accounted (set as 29.17 °C in thid study).

$$\ln(M) = -0.0152 - 0.279 \ln(L_\infty) + 0.6543 \ln(K) + 0.463 \ln(T),$$

where; L_∞ is the asymptotic length, K is the growth coefficient and T is the mean annual habitat temperature.

The fishing mortality rate (F) was determined by subtracting M from Z. The exploitation rate (E) was calculated using the formula $E = F/Z$. The relative yield per recruit analysis (Y'/R), introduced by Beverton and Holt (1957) as the alternative of yield per recruit model, suggested by Gulland (1969), is used to examined the optimum fishing intensity, which required less input parameters and can be written as,

$$Y'/R = EU^{\frac{M}{K}}\left\{1 - \frac{3U}{(1+m)} + \frac{3U^2}{(1+2m)} + \frac{3U^3}{(1+3m)}\right.$$

where, U = 1-(L_c/ L_∞), L_c = length at first capture, m = (1-E)/(M/K) = (K/Z)

Results

Age composition of *R. kanagurta* samples from the Eastern GoT, ranged from size 175-235 mm (Fig. 2), was between 0.44 and 1.25 years old, with average 0.78 ± 0.18 years old. The VBGF was fitted to size of length-at-age data using non-linear least-squares, which yielded the L_∞ as 214.37 mm. Meanwhile, the curvature (*K*) parameter of the VBGF was 4.24 yr^{-1} (Table 2; Fig. 3). The ø'-values was 3.29, as also showed in Table 2.

Total mortality rate (*Z*) was estimated at 6.09 yr^{-1} by the Hoenig' formula. Natural mortality (*M*)- and fishing mortality (*F*)- rates were 2.70 and 3.39 respectively (Table 2). The M/K value, which will used as the input parameter for the relative yield per recruit analysis was 0.64 and the current exploitation rate (E) was 0.56 (Table 2) respectively.

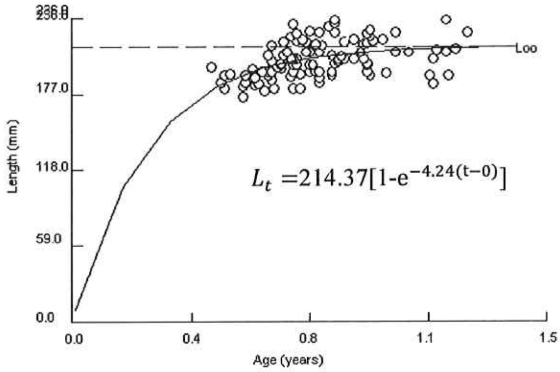

Figure 3. The von Bertalanffy growth model of *R. kanagurta* in the Eastern Gulf of Thailand

Table 2. Estimated population parameters of *R. kanagurta* in the Eastern Gulf of Thailand

Population parameters	Result
Asymptotic length (L_∞) in mm	214.37
Growth coefficient (K yr^{-1})	4.24
Growth performance index (ø')	3.29
Natural mortality (M yr^{-1})	2.70
Fishing mortality (F yr^{-1})	3.39
Total mortality (Z yr^{-1})	6.09
Exploitation level (E)	0.56
Sample size (N)	103

The relative yield per recruit as a function of length at first capture (L_c) and *M/K* value was estimated for *R. kanagurta* in the Eastern part of Thailand and the results were showed in Fig. 4. The results indicated that, at the present situation, the relative yield per recruit was estimated to be around 0.10 g with the maximum exploitation rate (E_{max}) at 0.49, which implied that the present level of exploitation rate (0.56) was higher than both E_{max} and the exploitation rate with maintain 50% of the stock biomass as spawning stock ($E_{0.5}$) at 0.32.

The graphically relative yield per recruit isopleths diagram of *R. kanagurta* from the Eastern Gulf of Thailand was showed in Fig. 5. From the diagram, it is suggested that a suitable L_c of *R. kanagurta* was between 150.06 and 214.37 mm. Meanwhile the fishing pressure, i.e. *E*-value, should have been between 0.60 and 1.00 yr^{-1}, which consequently indicated that the *F*-value should lied between 3.65 and 6.09 yr^{-1}. Under this condition, the Y'/R was estimated to be closely the maximum Y'/R.

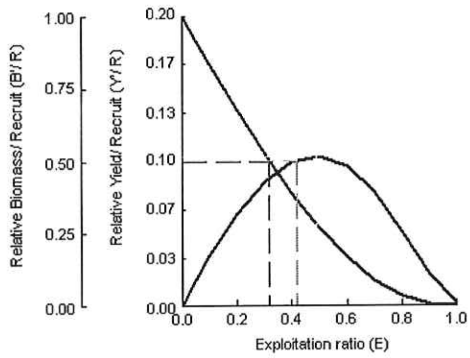

Figure 4. Two dimension relative yield per recruit of *R. kanagurta* from the Eastern Gulf of Thailand.

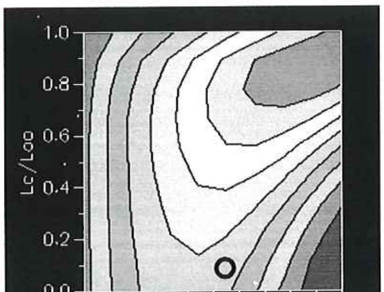

Figure 5. Relative yield per recruit isopleths diagram and the actual value (○) of *R. kanagurta* from the Eastern Gulf of Thailand.

Discussion

Information on age and growth of fishes are important input data fo: fish population dynamic, stock assessment and fisheries management (Morales-Nin, 2000; Campana, 2001; Mehanna, 2001; Cadima, 2003; Lombarte *et al.,* 2003). The study on age and growth in tropical fishes was commonly performed by length frequency data, i.e. length based calculation, because the difficulty of identifying age and growth directly on otolith or other hardpart of tropical fishes (Srinoparatwatana, 2009). However, the length based method *per se* required continuous data, i.e. at least 12 months of data collection, and also needed high number of fish samples. In addition, the length based method also difficulty to proceed, according to complexity of assessed protocols (Hoenig *et al.*, 1987). Nonetheless, challenging by the advance technique, such as cutting machine, high resolution microscope and computer program, the age based calculation in tropical fishes was increased rapidly (Campana, 2001). In this study, age calculation of *R. kanagurta* can be performed by polishing the thin cross-section otoliths of *R. kanagurta* with micro-sand paper until daily ring was appeared. Then, the ageing method based on increment thickness, coupled with the ImageJ picture analysis program, was applying to calculated age of individual fish.

The growth performance indice (ø') from this study (3.29) was lied within other ø'-values from both age and length based calculation, i.e. 2.76-3.31 (Lavapie-Gonzales *et al.*, 1997; Mehanna, 2001; Al-Mahdawi and Mehanna, 2010; Sumontha *et al.*, 2010; Thongsila *et al.*, 2012), implying that the estimated growth parameters were reliable. The mortality rates, obtained in this study, were similarity with the study from the whole Gulf of Thailand, i.e. Z=5.32 yr^{-1}, M=2.56 yr^{-1} and F= 2.76 yr^{-1} (Thongsila *et al.*, 2012) but Z and F were slightly lower than the study from the Andaman Sea, Z=8.18 yr^{-1}, M=1.40 yr^{-1} and F= 6.78 yr^{-1} (Sumontha *et al.*, 2010). The difference mortality rates in these two areas were caused by different stocks with different fishing pressure and consequent to the population parameters.

Pauly and Soriano (1986) used four-quadrant models to describe fish yield related to fish size. Quadrant A represents under fishing (L_c/L_∞=0.5-1.0 and E=0.0-0.5). Quadrant B represents eumetric fishing (L_c/L_∞=0.0-0.5 and E=0.0-0.5). Quadrant C represents developed fishery (L_c/L_∞=0.0-0.5 and E=0.5-1.0). Quadrant D represents overfishing (L_c/L_∞=0.0-0.5 and E=0.5-1.0). The relative yield per recruit isopleths of *R. kanagurta*, in this study, showed the position of actual value of *R. kanagurta* in the area of quadrant D (Fig. 5), since the ratio of L_c and L_∞ was 0.14 and the exploitation rate (E) was 0.56. The fishing charisteristic in the quadrant D was explaned by the small fish were caught at high effort levels and the possible management regime for this quadrant were increase size at first capture (L_c) and decrease fishing pressure, i.e. E-value (Pauly and Soriano, 1986).

From the results, the possible fisheries management regime, for *R. kanagurta* stock in the Eastern-GoT, is increase size at first capture (L_c) and decrease fishing pressure, i.e. E-value. From this study, the length at first capture (L_c) between 150.06 and 214.37 millimeters and the 0.50 optimum level of exploitation (E) suggested by Gulland (1971) were recommend. Meanwhile the length at first maturity, spawning biology and the regulation for protect mature parental stock during spawning season need to further investigate for sustaining the *R. kanagurta* stock in this fishing ground.

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References

Al-Mahdawi Gh.J. and Mehanna, S.F. (2010). Stock assessment of the Indian mackerel *Rastrelliger kanagurta* (Cuvier, 1816) in the Yemeni coast of Red Sea, Al-Hodeidah region. pp 220-230 In the Proceedings of the 3rd Global Fisheries and Aquaculture Research Conference, Foreign Agricultural Relations (FAR), Egypt.

Amin, S.M.N., Mohd Azim, M.K., Fatinah, S.N.J., Arshad, A., Rahman, M.A. and Jalal, K.C.A. (2014). Population parameters of *Rastrelliger kanagurta* (Cuvier, 1816) in the Marudu Bay, Malaysia. Iranian Journal of Fisheries Sciences 13(2): 262-275.

Bertalanffy, L.von. (1938). A quantitative theory of organic growth (inquiries on growth laws II). Human Biology 10(2): 181–213.

Beverton, R.J.H. and Holt, S.J. (1957). On the dynamics of exploited fish populations. Ministry of Agriculture, Fisheries and Food, London.

Cadima, E.L. (2003). Fish stock assessment manual. FAO Fisheries Technical Paper. No. 393. FAO, Rome.

Campana, S.E. (2001). Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. Journal of Fish Biology 59: 197–242.

Campana S.E. and Neilson J.D. (1985). Microstructure of fish otoliths. Canadian Journal of Fisheries and Aquatic Sciences 42(5): 1014-1032.

Chambers, R.C. and Miller T. J. (1995). Statistical analysis of reconstructed life histories from otoliths: Special properties of longitudinal data. pp 155 -175 In D. Secor, J. Dean and S. E. Campana (eds.). Recent Developments in Otolith Research. University of South Carolina Press, Columbia.

Fishery statistics analysis and research group. (2016). The marine fisheries statistics 2014. Department of Fisheries, Thailand.

Gayanilo, F.C. Jr., Sparee P. and Pauly, D. (1996). The FAO-ICLARM Stock Assessment Tools (FiSAT) User's Guide. FAO Computerized Information Series (Fisheries). No. 8., FAO, Rome

Gulland, J.A. (1969). Manual of methods for fish stock assessment part1: Fish population analysis. Food Agriculture Organization of the United Nations, Rome.

Gulland, J.A. (1971). The fish resources of the ocean. Fishing News, West Byfleet.

Hoenig, J.M. (1982). Estimating mortality rate from the maximum observed age. ICES Conference and Meeting 5(1): 1-5.

Hoenig, J.M., Csirke, J. Sanders, M.J. Abella, A., Andreoli, M.G., Lev, D., Ragonese, S., Al-shoushani M. and El-Musa, M.M. (1987). Data acquisition for length-based stock assessment report of working group 1, pp. 343–352 In ICLARM Conference Proceedings on Length-Based Methods in Fisheries Research, Vol. 13. ICLARM, Manila.

Jones, C.M. (1992). Development and application of the otolith technique. pp 1-11 In D.K. Stevenson and S.E. Campana (eds.). Otolith microstructure examination and analysis. Can. Spec. Publ. Fish. Aquat. Sci. 117. Bedford Institute of Oceanography, Canada.

Khrueniam, U., Charoensombat, B., Yangphonkhan, B. and Munprasit, R. (2013). Some biology of Indo-Pacific mackerel (*Rastrelliger brachysoma* (Bleeker, 1851)) and Indian mackerel (*R. kanagurta* (Cuvier, 1816)) in Trat Province, 2009. Department of fisheries, Thailand.

Koolkalya, S., Sawusdee, A. and Jutagate, T. (2015). Chronicle of marine fisheries in the Gulf of Thailand: variations, trends and patterns. Indian Journal of Geo-Marine Sciences 44(9): 1302-1309.

Lavapie-Gonzales, F., Ganaden, S.R. and Gayanilo, F.C.Jr. (1997). Some population parameters of commercially important fishes in the Philippines. Bureau of Fisheries and Aquatic Resources, Philippines.

Lombarte, A., Torres G.J. and Morales-Nin, B. (2003). Specific *Merluccius* otolith growth patterns related to phylogenetics and environmental factors. Journal of the Marine Biological Association of the United Kingdom 83: 277-281.

Luther, G. (1995). Fishery and resource characteristics of mackerel of Visakhapatnam coast. Marine Fisheries Information Services 138: 1-5.

Marine fisheries laboratory. (1965). Report on mackerel investigations 1963-1965. Department of Fisheries, Thailand.

Mehanna, S.F. (2001). Population dynamics and fisheries management of the Indian mackerel *Rastrelliger kanagurta* in the Gulf of Suez, Egypt. Journal of King Abdulaziz University (Marine Sciences) 12: 217-229.

Morales-Nin, B. (1992). Determination of growth in bony fishes from otolith microstructure. FAO Fisheries Technical Paper. No. 322. FAO, Rome.

Morales-Nin B. (2000). Review of the growth regulation processes of otolith daily increment formation. Fisheries Research 46:53–67.

Pauly, D. (1980). On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Journal du Conseil/Conseil Permanent International pour l'Exploration de la Mer 39(3): 175-192.

Pauly, D. and Soriano, M.L. (1986). Some practical extensions to Beverton and Holts relative yield- per-recruit model. The first Asian Fisheries Forum (pp. 491-496). Asian Fisheries Society, Manila.

Rasband, W.S. (2016). ImageJ. Bethesda, MD: National Institute of Health, Maryland, USA.

Sumontha, M., Boonsuk, S., Panjarat, S., Jaiyen, T. and Ritthisaman J. (2010). Stock assessment of Indian Mackerel (*Rastrelliger kanagurta* (Cuvier, 1816)) along the Andaman Sea, Coast of Thailand. Department of Fisheries, Thailand.

Srinoparatwatana C. (2009). Population biology of two key fish species and the dynamics and management of the trap fishery in Beung Borapet, Thailand. Ph.D. thesis, Edith Cowan University, Perth.

Thongsila, K., Sinanun, T., Noranarttragoon, P., Boonjorn, N and Khemakorn, P. (2012). Stock assessment of Indian mackerel (*Rastrelliger kanagurta* (Cuvier, 1816)) in the Gulf of Thailand. Department of fisheries, Thailand.

Wilson, K. H. and Larkin, P. A. (1980). Daily growth rings in the otoliths of juvenile sockeye salmon (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Sciences 37(10): 1495-1498.

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