FORECASTING PELAGIC FISH IN MALAYSIA USING ETS STATE SPACE APPROACH

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I dedicate this work to my family.

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ABSTRACT

Modelling and forecasting fish catch has been undertaken for a long time over the world. However, From time to time, researchers are always looking for a new model that can predict more accurately the number of fish catch. The objective of this study is to propose the Error Trend and Seasonal (ETS) state space approach.In this study, two techniques of time series analysis were used to forecast fish catch of three commercial fish species found in the Malaysian waters. One of such techniques is the Box-Jenkins method which concerns the building of linear and stochastic dynamic models with minimum data requirements. The second technique is the Error Trend and Seasonal (ETS) state space exponential method which requires no assumptions about the correlations between successive values of the time series. The two class models were used to model and forecast two years monthly catches of the three fish species based on the collected data for the period 2007 – 2011. The SARIMA(1,1,1)(0,0,1)[12], SARIMA(1,1,4)(0,0,1)[12], SARIMA(2,1,1)(0,0,1)[12] and ETS (M, A, M), ETS (M, N, M), ETS (M, A, M) for *Dussumiera acuta* (tamban buloh), *Rastrelliger kanagurta* (kembong) and *Thunnus tonggol* (Tongkol hitam) were proposed respectively. The diagnostic checking for all the fitted models confirmed the adequacy of the models. Results based on the root mean square error (RMSE) and mean absolute error (MAE) demonstrated that the ETS models performed better for *Thunnus tonggol* and *Rastrelliger kanagurta*, while SARIMA model performed better for *Dussumiera acuta*. This shows that ETS model which has so far not been used in fisheries in Malaysia is our main contribution in this research. Nevertheless, both models have proven successful in describing and forecasting the monthly fishery dynamics. These forecasts proves helpful in formulating the needed strategies for sustainable management and conservation of the stocks, and can also help the decision makers to establish priorities in terms of fisheries management.

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ABSTRAK

Permodelan dan ramalan tangkapan ikan telah dijalankan untuk masa yang lama di seluruh dunia. Namun, terdapat masalah dalam mencari model yang sesuai yang boleh memperoleh dinamik data tang sebagai atribut kepada data tangkapan ikan. Dari masa ke semasa, penyelidik sentiasa mencari model baru yang boleh meramal lebih tepat lagi beberapa tangkapan ikan. Dalam kajian ini, dua teknik analisis siri masa telah digunakan untuk meramal hasil tangkapan ikan daripada tiga spesies ikan komersial yang terdapat di perairan Malaysia. Salah satu teknik itu adalah kaedah Box-Jenkins yang berkaitan dengan pembinaan model dinamik linear dan stokastik dengan keperluan data minimum. Teknik yang kedua ialah ETS keadaan ruang kaedah eksponen yang tidak memerlukan andaian tentang hubungan antara nilai-nilai berturut-turut siri masa. Kedua-dua kelas model digunakan untuk dimodelkan dan meramal dua tahun tangkapan bulanan daripada tiga spesies ikan berdasarkan data yang dikumpul bagi tempoh 2007 - 2011. SARIMA (1,1,1) (0,0,1)[12], SARIMA (1,1,4) (0,0,1)[12], SARIMA (2,1,1) (0,0,1)[12] dan ETS (M, A, M), ETS (M, N, M) , ETS (M, A, M) untuk *Dussumiera acuta* (tamban Buloh), *Rastrelliger kanagurta* (Kembong) dan *Thunnus tonggol* (Tongkol hitam), telah dibangunkan. Semakan diagnostik untuk semua model dipasang mengesahkan kecukupan model. Keputusan berdasarkan punca min ralat kuasa dua (RMSE) dan bermakna ralat mutlak (MAE) menunjukkan prestasi model ETS lebih baik untuk *Thunnus tonggol* dan *Rastrelliger kanagurta*, manakala prestasi model SARIMA lebih baik untuk *Dussumiera acuta*.Ini menunjukkan model ETS yang belum pernah digunakan di perikanan Malaysia ialah penyumbang utama dalam kajian ini. Walau bagaimanapun, kedua-dua model telah terbukti berjaya dalam menerangkan dan meramal dinamik perikanan bulanan. Ramalan boleh membantu dalam merangka strategi yang diperlukan untuk pengurusan dan pemuliharaan stok yang berterusan, malah membantu pembuat keputusan untuk menubuhkan keutamaan dari segi pengurusan perikanan.

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LIST OF ABBREVIATIONS

ARIMA	Autoregressive Integrated Moving Average
SARIMA	Seasonal Autoregressive Moving Average
AIC	Akaike Information Criteria
ACF	Autocorrelation Function
PACF	Partial Autocorrelation Function
RMSE	Root Mean Square Error
ETS	Error Trend Seasonal
FAD	Fish Aggregation Device
MAE	Mean Absolute Error

APPENDIX

CHAPTER 1

INTRODUCTION

1.0 Introduction

Fisheries management appeals on fisheries science in order to find ways to protect fishery resources for a possible sustainable exploitation. Modern fisheries management often referred to as a governmental system of appropriate management rules based on defined objectives and a mix of management means to implement the rules, which are to put in place by a system of monitoring, control and surveillance. The integrated process of information gathering, analysis, planning, consultation, decision making, and allocation of resources, formulation and implementation, with enforcement is necessary as regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources are among other fisheries objectives.

Effective management is essential if marine resources are to be utilized in a sustainable and a responsible manner. Sustainable and responsible fisheries management is of a fundamental importance as fisheries are one of the main pillars of the Malaysian economy. Given this fact, this work studied the fisheries dynamics of some selected fishes commonly found in Malaysian waters using two time series analysis techniques. Time series analysis is an economical method for forecasting fish catches which are essential for fisheries management. It describes the time structure of the catch data (Noble and Sathianandan, 1991). Many fields like agriculture, environmental, economics, tourism, meteorology and fisheries have been forecasted using time series models (Mahendran et al., 2008). This study evaluated, modeled and forecasted the Malaysian fish catches for some selected fish species using SARIMA and ETS state space approach. SARIMA is a common model used by many researchers e.g, Hae-hoon park (1998), Geogakarakos et al. (2012) whereas ETS state space approach has never been used in fisheries research in Malaysia

1.1 Background of the study

The fisheries sector plays an important role in the Malaysian national economy. It contributes to the national Gross Domestic Product (GDP), it is also a source of employment, foreign exchange and source of chief protein supply for the urban and rural population in the country. Fish constitutes 60-70% of the national animal protein intake, with per capita consumption of 47.8 kg per year (Che Ayub, 2012).

The rate of demand for fish as the main source of protein is expected to increase from the current population of 26,330 000 with a per capita consumption of 60 kg/year. In 1997, the fisheries sector contributed 1.57% to GDP, and it provides employment for more than 79,000 fishermen and 20,000 fish farmers. In 2003, the total fish production amounts to 1,483,958 tons valued at RM5.22 billion (US$ 1.36 billion). This contributed to about 1.37% of Gross Domestic Product (GDP) and provided direct employment to 89,433 fishers and 21,114 fish aqua culturists (Annual Fisheries Statistic, 2003), and also production of 1.71 million tons valued at RM 8.546 billion in 2009 (Che Ayub, 2012).

Malaysia has one of the highest intakes of fish in the world with estimated consumption in excess of 50kg per person, per year and accounting for approximately 60% of total animal protein intake (Azam-Ali et al. 2012).Approximately 75% of the fish harvested in Malaysia are wild, and caught from the marine environment. The Malaysian fisheries sector is divided into two: the capture fisheries (marine and inland) and the aquaculture. The marine capture fisheries cover a total area of 547,200 km^2 and categorized into coastal fisheries and deep-sea fisheries. In 2003, the coastal fisheries and deep-sea fisheries contributed about 1,084,802 tons (73.1%) and 198,453 tons (13.4%) respectively, to the total marine landings. There are more than 100 commercial fish species found in the Malaysian waters. The Malacca Straits and the South China Sea are the two main fishing areas which contribute most to Malaysian marine fishery and the rest are Sulu and Sulawesi seas in the east coast of Sabah.

Pelagic fishes are among the important contributor of deep sea catch. Pelagic fish refers to those fish that spend most of their life swimming in the water column (seas, oceans or open waters which associated with the surface or middle depths of a water body) with little contact with or dependency on the bottom of the sea floor. Many pelagic fish feed on plankton. The important pelagic fishes found in Malaysian waters include mackerel, tuna and sardines. Since fisheries resources are renewable, proper management issues should be taken to manage these fisheries resources. One of the issues is to forecast the upcoming fish catch. Fish forecasting is a very important tool for fisheries managers and scientists to enable them to decide on sustainable management issues.

1.2 Common fish species found in Malaysian waters

Tuna, mackerel, and sardines are some of the common fish species distributed over warmer oceans in the world (Campbell, 2008), and they are found to be common in Malaysian waters (Table 1.1; Noraish and Raja 2009; Samsudin 2012).

1.2.1 The Tuna Fish

The tuna fish are fast growing species with a catch size ranging from 1.8kg - 684kg depending on the type of species. Tuna spawn once a year and they are broadcast spawners, that is, they scatter their eggs into open water and fertilize externally. Tuna are known to make seasonal excursions to higher latitudes as water temperatures increase with season. A spawning female may release as many as 100,000 eggs per 2.2 pounds (1 kg) of body weight. The age of tuna at sexual maturity ranges from three to five years, depending on the species. Several popular species of tuna are being over fished, while others are sustainable. Other species are either already endangered or may soon become so (Langley et al. 2002). The majority of tuna are caught using one of the following methods; hook and line, purse seine, or gill net. Table 1.1 gives the most common tuna species found in Malaysian waters (Samsudin et al. 2012).

Table 1.1**:** Tuna fish species found in Malaysian waters

Fish	**Scientific Name**	**English Name**	**Local Name**	**Plate**
Tuna	*Thunnus tonggol*	Longtail tuna	Tongkol hitam	1.1
	Thunnus albacores	Frigate tuna	Tongkol selasih	1.2

Plate 1.1**:** *Thunnus tonggol* (Bleeker, 1851) or commonly called tongkol hitam

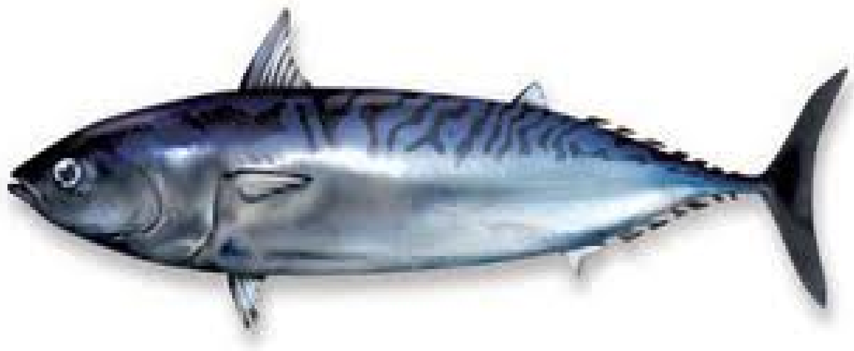

Plate 1.2**:** Thunnus albacores (Bonnaterre, 1788) or commonly called tongkol selasih

1.2.2 The Mackerel

Similar to the tuna family, mackerels share a family with the many species of tuna. Like tuna, they live in saltwater environments, usually in warm or temperate regions. Mackerel are typically an open ocean fish with greedy feeding habits, and may grow as large as 7.5 lb with maximum age of 20 years depending on the species; most species reach maturity at the age of two (Shuman, 2013). Although over fishing has started to be a problem it is expected that mackerel stock remain stable for few more year. Mackerel spawn near the surface and the eggs float in the water. Some methods used in catching mackerel are: spinning, floating, hook and line. Some mackerel species found Malaysian in waters (Samsudin et al. 2012) are displayed in table 1.2.

Table 1.2**:** Mackerel fish species found in Malaysian waters

Fish	**Scientific Name**	**English Name**	**Local Name**	**Plate**
Mackerel	*Rastrelliger kanagurta*	Indian mackerel	Kembong	1.3
	Rastrelliger brachysoma	Short mackerel	Pelaling	1.4
	Scrobemorus gattatus	King mackerel	Tenggiri papan	1.5
	Scrobemorus commerson	Spanish mackerel	Tenggiri batan	1.6

Plate 1.3: *Rastrelliger kanagurta* (Cuvier, 1817) or commonly called Kembong

Plate1.4**:** *Rastrelliger brachysoma* (Bleeker, 1851) or commonly called pelaling

Plate1.5: *Scombemorus gattatus* (Bloch & Schneider, 1801) or commonly called tenggiri papan

Plate1.6: *Scrobemorus commerson* (Lacepede, 1800) or commonly called tenggiri batan

1.2.3 The Sardines

Sardines are also among the most abundant and commercially important fish species in many countries around the world and are soft-boned fish that travel in schools. This fish range from 2.5 - 8.5 inches and weigh less than 1.0 lb. The sardine is a batch spawner and water temperature is very important environmental factor for their spawning dynamics (Ana et al. 2010). Some methods of catching sardine include; purse seine, hook and line. Sardine species found Malaysian in waters (Samsudin et al. 2012) are given in Table 1.3.

Table 1.3: Sardine fish species found in Malaysian waters

Fish	Scientific Name	English Name	Local Name	Plate
Sardine	*Sardinella fimbriata*	Fringe Scale	Tamban Sisek	1.7
	Dussumiera acuta	Rainbow Sardine	Tamban buloh	1.8
	Amblygaster leiogaster	Smoothbelly Sardine	Tamban Beluru	1.9

Plate1.7: *Sardinella fimbriata* (Valenciennes, 1847) or commonly called tamban sisek

Plate1.8: *Dussumiera acuta* (Valaenciennes, 1847), or commonly called Tamban buloh

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