Research Journal of Mathematical and Statistical Sciences ISSN 2320–6047
Vol. **2(11),** 1-8, December **(2014)** *Res. J. Mathematical and Statistical Sci.*

Determinating the Utilization Status and Management Scenarios of Bonito (*Auxis Rochei*) Catching in Talaud Waters North Sulawesi

John S. Kekenusa[1]*, Sendy B. Rondonuwu[2], Marline S. Paendong[1] and Winsy Ch. D. Weku[1]
[1]*Lecturer at Department of Mathematics, Faculty of Mathematics and Natural Science, Sam Ratulangi University, INDONESIA
[2]Lecturer at Department of Biology, Faculty of Mathematics and Natural Science, Sam Ratulangi University, INDONESIA

Available online at: www.isca.in, www.isca.me
Received 30th October 2014, revised 19th November 2014, accepted 11th December 2014

Abstract

Bonito (Auxis rochei), needs to be managed well because even as a renewable natural resource, but can undergo depletion or extinction. One of the approach in the management of fish resources is by modeling. The analysis was performed aiming to get the best estimate for the surplus production model to determine the maximum sustainable yields (MSY), utilization level, and effort level of bonito. The data of catch and fishing effort bonito collected from the Marine and Fisheries Service of the Talaud Regency and the North Sulawesi Province. Best Surplus Production Model, which is used to assess the potential of bonito is Schaefer Model. Optimal effort (E_{MSY}) of 8,489 trips per year, with catches of optimal C_{MSY} 2,453.77 tons per year. The effort level for 2012 is 193.99%, which shows the inefficiency of effort, the utilization level of 94.86%, showing indicate will occur overfishing.

Keywords: Bonito, Surplus Production Model, Maximum Sustainable Yield, Talaud.

Introduction

Bonito (*Auxis rochei*) classified as pelagic fishery resource is important and one of the non-oil export commodity in North Sulawesi. Bonito production in North Sulawesi (including Talaud waters) in 2011 reached 30,000 tons per year, with a value of about 300 billion rupiahs[1]. Research on bonito generally discusses the exploitation to increase production, not much research on the status of utilization (including aspects of sustainability and efficiency) resources. Catching bonito in waters Talaud has lasted long enough, with high intensity. Data on the level of utilization of the fish resources are very important, as it will determine whether the resource use is less than optimal, optimal, or excessive. Excessive utilization of fish resources would threaten its sustainability. By knowing the level of resource utilization on the bonito, is expected to be done in a planned and sustainable management.

The simplest model of the dynamics of fish populations is Surplus Production Model (SPM), by treating the fish as a single biomass that can not be divided, which is subject to the rules of simple increases and decreases in biomass. This model, commonly used in the assessment of fish stocks using only the data of catch and fishing effort generally available.

This study aims to get the best SPM, as well as knowing how much the result of maximum sustainable yields (MSY), utilization level, and the level of effort of bonito in the Talaud waters.

Surplus Production Model: The simplest model of the dynamics of fish populations is a surplus production model that treats the fish population as a single biomass that can not be divided, which is subject to the simple rules of the rise and decline. The production model is dependent on the amount of four kinds, namely: biomass population at a given time t (B_t), catches for a certain time t (C_t), fishing effort at a certain time t (E_t), and the natural growth rate constant (r) [2]. This model was first developed by Schaefer, who was initially the same as the form of logistic growth model.

According to Coppola and Pascoe[3], equation surplus consists of several constants that are affected by natural growth, the ability of fishing gear, and carrying capacity. Constants allegedly using models of biological parameter estimators of surplus production equation, namely the model: Equilibrium Schaefer, Schaefer Disequilibrium, Schnute and Walter- Hilborn. Based on the four models were selected the most appropriate or best fit of the estimation of others.

According to Sparre and Venema[4], formulas surplus production model is valid only if the slope parameter (b) is negative, which means the addition of fishing effort will lead to a decrease in the catch per fishing effort. If the parameter b positive value, then it can not be done estimating the optimum amount of stock and effort, but it can only be concluded that the addition of fishing effort is still possible to increase the catch.

Prediction of optimum fishing effort (E_{opt}) and the maximum sustainable catch (C_{MSY}) approached the surplus production model. Between the catch per unit of effort (CPUE) and fishing effort can be either linear or exponential relationship[5]. Surplus Production Model consists of two models, namely basic model of Schaefer (linear relationship) and the Gompertz model developed by Fox with forms exponential relationship[5].

Schaefer Model: Surplus production models first developed by Schaefer, who was initially the same as the form of logistic growth model. The model is as follows:

$$\frac{dB_t}{dt} = G(B_t) = r\,B_t\left(1 - \frac{B_t}{K}\right) \quad (1)$$

This equation does not include the effect of the catching, so Schaefer wrote back to: $\frac{dB_t}{dt} = r\,B_t\left(1 - \frac{B_t}{K}\right) - C_t$ (2)

K is the carrying capacity of the marine environment, and C_t is the catch that can be written as:

$$C_t = q\,E_t\,B_t \quad (3)$$

catchability, and Et indicates fishing effort. This equation can be written as: $\frac{C_t}{E_t} = q\,B_t = \text{CPUE}$ (4)

From the differential equation (2), the optimum catchment can be calculated at the time $\frac{dB_t}{dt} = 0$, also called settlement at the point of balance (equilibrium), in the form of: $r\,B_t\left(1 - \frac{B_t}{K}\right) - C_t = 0$, or $C_t = r\,B_t\left(1 - \frac{B_t}{K}\right) = q\,E_t\,B_t$ (5)

From equation (3) and (5), find value of B_t obtained as follows:

$$B_t = K\left(1 - \frac{qE_t}{r}\right) \quad (6)$$

So that equation (5) becomes:

$$C_t = q\,K\,E_t\left(1 - \frac{qE_t}{r}\right)$$

$$= q\,K\,E_t - \frac{q^2K}{r}E_t^2 \quad (7)$$

Equation (7) is simplified further by Schaefer becomes:

$$\frac{C_t}{E_t} = a - b\,E_t\text{, or } C_t = a\,E_t - b\,E_t^2 \quad (8)$$

while the $a = q\,K$ and $b = \frac{q^2K}{r}$.

This linear relationship is used widely for calculating C_{MSY} through the determination of the first derivative of C_t with E_t to find optimal solutions, both to catch and fishing effort. The first derivative of C_t to Et is: $\frac{dC_t}{dE_t} = a - 2b\,E_t$, in order to obtain the alleged E_{opt} (optimum fishing effort) and C_{MSY} (maximum sustainable yields) respectively:

$$E_{opt} = \frac{a}{2b} = \frac{r}{2q} \quad (9)$$

by entering the value of E_{opt} in equation (8), will be obtained C_{MSY} as follows: $C_{MSY} = a\,E_t - b\,E_t^2$

$$= a\left(\frac{a}{2b}\right) - b\left(\frac{a}{2b}\right)^2$$

$$= \frac{a^2}{4b}$$

by substituting $a = qK$ and $b = \frac{q^2K}{r}$ will be obtained,

$$C_{MSY} = \frac{a^2}{4b} = \frac{q^2K^2}{4q^2K/r} = \frac{rK}{4} \quad (10)$$

The values of a and b are estimated by the least squares method approach that is commonly used to estimate the coefficient of a simple regression equation. Furthermore, by including the value of E_{opt} in equation (6) is obtained optimum biomass (B_{MSY}) as follows:

$$B_{MSY} = K - \frac{Kq}{r}E_{opt}$$

$$= K - \frac{Kq}{r}\left(\frac{r}{2q}\right)$$

$$= K - \frac{K}{2}$$

$$= \frac{K}{2} \quad (11)$$

The values of the parameter q, K, and r can be calculated using the Fox algorithm, as referenced in Sularso[6], as follows:

$$q_t = \ln\left[\left[\left(zU_t^{-1} + \frac{1}{b}\right)/\left(zU_{t+1}^{-1} + \frac{1}{b}\right)\right]\right]/(z) \quad (12)$$

where $z = -(a/b)/E^*$, $E^* = (E_t + E_{t+1})/2$, $U_t = \frac{C_t}{E_t}$ and the value of q is the geometric mean of the value of q_t. From the values of a, b, and q, can then be calculated values of K and r.

Fox Model: Model of Fox has several characteristics that are different from the model Schaefer, that it biomass growth following the Gompertz growth model[7]. The relation of CPUE with effort (E) follows a negative exponential pattern:

$$C_t = E_t \,.\, \exp(a - b\,E_t) \quad (13)$$

Efforts optimum is obtained by equating the first derivative of Ct to E_t equal to zero and find:

$$E_{opt} = \frac{1}{b} \quad (14)$$

The maximum sustainable yields of catch (C_{MSY}) is obtained by inserting the value of the optimum effort into equation (13), and obtained:

$$C_{MSY} = \frac{1}{b} e^{a-1} \quad (15)$$

Schnute Model: Schnute, suggests another version of the surplus production model is dynamic and deterministic[8]. Schnute method is considered as a modification of the model in the form of discrete Schaefer[9].

$$\ln(\frac{U_{t+1}}{U_t}) = r - \frac{r}{qK} (\frac{U_t + U_{t+1}}{2}) - q (\frac{E_t + E_{t+1}}{2})$$

$$= a - b (\frac{U_t + U_{t+1}}{2}) - c (\frac{E_t + E_{t+1}}{2}) \quad (16)$$

where a = r, b = $\frac{r}{qK}$, and c = q, is the regression coefficient estimators.

Walter - Hilborn Model: Walter and Hilborn (1976) referred by Tinungki[9], to develop other types of surplus production model, known as the regression model. Walter - Hilborn Model, using a simple differential equation, by the following equation:

$$\frac{U_{t+1}}{U_t} - 1 = r - \frac{r}{Kq} U_t - q E_t$$

$$= a - b U_t - c E_t \quad (17)$$

where a = r, b = $\frac{r}{Kq}$, and c = q, is the regression coefficient estimators.

Clarke Model Yoshimoto Pooley (CYP): Estimation of biological parameters for the surplus production model can also be done through estimation techniques proposed by Clarke, Yoshimoto, and Pooley[10]. The parameters which allegedly is r, K, and q, the model is expressed as follows:

$$\ln(U_{t+1}) = \left(\frac{2r}{2+r}\right)\ln(qK) + \frac{2-r}{2+r}\ln(U_t) - \frac{q}{2+r}(E_t + E_{t+1}) \quad (18)$$

where: $a' = \frac{2r}{2+r}$, $a = a'\ln(qK)$, $b = \frac{2-r}{2+r}$, $c = \frac{q}{2+r}$

thus equation (18) can be written in the form:

$$\ln(U_{t+1}) = a' \ln(qK) + b\ln(U_t) - c(E_t + E_{t+1})$$

$$= a + b\ln(U_t) - c(E_t + E_{t+1}) \quad (19)$$

Methodology

Source of Data: The primary and secondary data of bonito catching is collected from the Talaud waters. Production and fishing effort data collected from the Marine and Fisheries Service of Talaud Regency and North Sulawesi Province during the years 2003-2012.

Data (variables) used for the analysis of the surplus production model is the data of the catch (C_t) per year and fishing effort (E_t) per year, and CPUE (Catch Per Unit of Effort). The data (variables) used for the analysis of the surplus production model is as follows: i. The catch (C_t): weight of fish landed (tons) in year t

The Effort of catching (E_t) : the number of fishing boat landing result in a landing (trip) in year t

$\frac{C_t}{E_t}$ Catch per Unit of Effort (tons per trip) in year t

Methods of Data Analysis: The models estimator who analyzed and evaluated are: Schaefer, Fox, Schnute, Walter-Hilborn, and Clarke-Yoshimoto-Pooley (CYP). Based on the results of statistical evaluation (mark of conformity, the value of R^2, the validation value, and significance of the regression coefficient of the model), we get the "best" as estimator. From the best of model can be calculated C_{MSY} value, optimum fishing effort (E_{MSY}), utilization level, and the level of effort of boniti fishery.

Results and Discussion

Catches of bonito fisheries in the Talaud waters fluctuate from year to year. Data catching in 2003-2012, are presented in table 1.

Table-1
Total Catch, fishing efforts, and CPUE Tuna Taaud waters of 2003-2013

Years	Captured (tons)	Efforts (trip)	CPUE = $\frac{C_t}{E_t}$ (ton/trip
2003	1625,8	2931	.55469
2004	1778,3	3444	.51635
2005	1847,3	3531	.52585
2006	1941,0	2800	.69321
2007	1847,0	6825	.27062
2008	1951,8	8296	.23527
2009	1958,2	8246	.23747
2010	2215,7	8496	.26079
2011	2245,8	12096	.18566
2012	2327,6	16468	.14341
Mean	1973,85	7313	0.36233

Source: *Calculated from the Marine and Fisheries Service Talaud regrency and North Sulawesi Province data*

The results of the regression analysis for the surplus production model is presented in Appendix 1, which is described as follows**:**

Schaefer Model: From the analysis of regression equation C_t= 0.636 - 0.00003746 E_t, with a coefficient of determination (R^2) = 0.771 and a significance level of $p < 0.01$. Thus, a production model estimator catches Schaefer model according to the equation (8) is: $C_t = 0.636\ E_t - 0.00003746\ E_t^2$.

Fox Model: From the results of the regression analysis regression equation: Ln C_t = -0.313 - 0.000113 E_t, with R^2 = 0.897 ($p < 0.01$). Estimates of catches corresponding to the model Fox equation (13):
$C_t = E_t . e^{(-0.313 - 0.000113 E_t)}$

Schnute Model: Schnute method according to equation (16), obtained regression equation:

$$\ln\left(\frac{U_{t+1}}{U_t}\right) = 0.297 – 0.526\left(\frac{U_t + U_{t+1}}{2}\right) - 0{,}0000363\left(\frac{E_t + E_{t+1}}{2}\right)$$

with R^2 = 0,035, and all the regression coefficient was no significant ($p > 0.05$).

Walter Model – Hilborn: In Walter-Hilborn method using equation (17) derived regression equation

$$\frac{U_{t+1}}{U_t} - 1 = 1.617 - 2.358\ U_t - 0.000128\ E_t$$

With R^2 = 0.391 and all regression coefficients were not significant ($p > 0.05$).

Clarke Model Yoshimoto Pooley (CYP)
In the regression equation CYP method, according to equation (19) :

$$\ln(U_{t+1}) = -0.367 - 0.259 \ln(U_t) - 0.00007871(E_t + E_{t+1})$$

with R^2 = 0.851, and not all of the regression coefficient are significant.

Discussion: The results of calculations for validation surplus production model of 5 models is presented in Appendix 2, which is summarized in Table 2.

From the results of the calculations in Table 2, it appears that the most appropriate is Schaefer model with the R^2 value is quite large (R^2 = 0.771) and validation (residual value) is relatively small. Schaefer model obtained values of a = 0.636 and b = 0.00003746, with equation (9) and (10) can be calculated optimum value of Effort (E_{opt}) and the maximum sustainable catch (C_{MSY}) as follows:

$$E_{opt} = \frac{a}{2b} = \frac{0.636}{2(0.00003746)} = 8{,}489.054 \approx 8{,}489 \text{ trips per year.}$$

$$C_{MSY} = \frac{a^2}{4b} = \frac{0.636^2}{4(0.00003746)} = 2{,}453.77 \text{ ton per year.}$$

This means that in order to preserve the bonito fisheries resources technically and biologically, in a year the number of units should not exceed 8,489 trips. To preserve the bonito resources in the waters Talaud Islands, the maximum of fish that can be caught at 2,453.77 tons per year. Furthermore, from the value of E_{opt} and C_{MSY} can be calculated fishing effort levels and utilization level of bonito for a particular year for example in 2012, as follows:

$$\text{The level of effort in 2012} = \frac{E_{2012}}{E_{opt}} \text{ x } 100\%$$

$$= \frac{16{,}468}{8{,}489} \text{ x } 100\% = 193.99\ \%$$

$$\text{The utilization level in 2012} = \frac{C_{2012}}{C_{MSY}} \text{ x } 100\%$$

$$= \frac{2327{,}6}{2453{,}77} \text{ x } 100\% = 94.86\ \%.$$

From the calculation, it turns out bonito fishing effort at the Talaud waters in 2012, vastly exceeding the maximum sustainable level of effort. This shows that fishing effort is not very efficient. The utilization level for the year 2012, although not beyond the optimum level, however, be a sign of *overfishing* (catch-over). This study describes the use of some statistical criteria in selecting the best surplus production model. By applying some statistical criteria in selecting a surplus production model, will obtain better results. Researchers in the field of fisheries get guidelines for setting selection criteria for surplus production models, as well as avoiding the direct application of one model in analyzing the surplus production model in a waters.

Table-2
Results of the surplus production model validation

	Model Schaefer	**Model Fox**	**Model Schnute**	**Model Walter-Hilborn**	**Model CYP**
Sign Suitability	Appropriate	Not Appripriate	Appropriate	Appropriate	Not Appripriate
R^2 Value	0.771	0.897	0.035	0.391	0.851
Validation Value	0.19664	0.15574	0.85311	0.26546	0.77797
Significance Coefficient	Signifikan	Signifikan	Not significant	Not significant	Not significant

Conclusion

The surplus production model that can be used to examine the catch of bonito in the Talaud waters is Schaefer model, by the equation: $C_t = 0.636\ E_t - 0.00003746\ E_t^2$

The maximum sustainable yield of bonito C_{MSY} is 2453.77 tons per year, obtained at the level of fishing effort E_{MSY} 8,489 trips. For the year 2012 the amount of 94.86% utilization level is a sign of overfishing alert (overfished), with the level of effort for 193.99% indicating inefficiencies in fishing effort.

Ssuggestion: In applying surplus production models in a waters location, not only directly using one particular model, but should use some of the models are chosen based on statistical criteria. These criteria involve, among others: suitability sign of the coefficient of models, coeffient of determination (R^2), the value of validation, and the significance of the regression coefficients.

There are indications will occur overfishing, and the presence of inefficiency of fishing effort of bonito in the waters Talaud, recommended immediate supervision by competent institutions to handle this issue. Especially the efficiency of fishing effort.

Reference

1. Dinas Kelautan Dan Perikanan Provinsi Sulawesi Utara., Statistik Perikanan Tangkap Provinsi Sulawesi Utara Tahun 2011, **(2012)**

2. Boer M., Dan Azis K.A., Prinsip-prinsip Dasar Pengelolaan Sumberdaya Perikanan Melalui Pendekatan Bio-Ekonomi, *Jurnal Ilmu-ilmu Perairan dan Perikanan* **III(2),** 109-119 **(1995)**

3. Coppola G., and Pascoe S., A Surplus Production Model with a non-linear Catch-Effort Relationship, (Research Paper 105) Center for the Economics and Managemant of Aquatic Resources University of Portsmouth, **(1996)**

4. Sparre P. and Venema. S.C., Introduksi Pengkajian Stok Ikan Tropis. Buku 1 Manual. (Terjemahan J. Widodo. I.G.S. Merta, S. Nurhakim, dan M. Badrudin). Pusat Penelitian dan Pengembangan Perikanan, Badan Penelitian dan Pengembangan Pertanian (Kerjasama dengan Organisasi Pangan dan Pertanian Perserikatan Bangsa-bangsa), Jakarta, 438 hal **(1999)**

5. Gulland J.A., Fishing and Stock of Fish at Iceland, *Mui.`Agric. Fish Food, Invest. (Ser.2),* **23(4),** 52–70 **(1983)**

6. Sularso A., Alternatif Pengelolaan Perikanan Udang di Laut Arafura. Disertasi (Tidak Dipublikasikan), Sekolah Pascasarjana Institut Pertanian Bogor. Bogor. 130 hal, **(2005)**

7. Fox W.W., an Exponential Surplus Yield Model for Optimazing Exploited Fish Population, *Trans. Am. Fish Soc.,* **99(1),** 80-88 **(1970)**

8. Schnute J., Improved Estimates from the Schaefer Production Models: Theoretical Considerations, *J. Fish. Res. Board Can.,* **34,** 583-663 **(1977)**

9. Tinungki G.M., Evaluasi Model Produksi Surplus dalam Menduga Hasil Tangkapan Maksimum Lestari untuk Menunjang Pengelolaan Perikanan Lemuru Di Selat Bali. Disertasi (Tidak Dipublikasikan). Sekolah Pascasarjana Institut Pertanian Bogor. Bogor. 207 hal, **(2005)**

10. Fauzi A., dan S. Anna., Pemodelan Sumberdaya Perikanan dan Kelautan untuk Analisis Kebijakan. PT. Gramedia Pustaka Utama, Jakarta, **(2005)**

Appendix-1
Regression analysis of Surplus Production Model of bonito data in Talaud Waters

Model Schaefer

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.878[a]	.771	.743	.09661061
a. Predictors: (Constant), Et				

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.636	.061		10.440	.000
	Et	-3.746E-005	.000	-.878	-5.195	.001
a. Dependent Variable: Ut						

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	.252	1	.252	26.985	.001[b]
	Residual	.075	8	.009		
	Total	.327	9			

a. Dependent Variable: Ut
b. Predictors: (Constant), Et

Model Fox

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.947[a]	.897	.885	.18150109
a. Predictors: (Constant), Et				

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.306	1	2.306	70.009	.000[b]
	Residual	.264	8	.033		
	Total	2.570	9			
a. Dependent Variable: Ln Ut						
b. Predictors: (Constant), Et						

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.313	.115		-2.734	.026
	Et	.000	.000	-.947	-8.367	.000
a. Dependent Variable: Ln Ut						

Model Schnute

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.188[a]	.035	-.286	.39571729
a. Predictors: (Constant), (Et + Et+1)/2, (Ut + Ut+1)/2				

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.034	2	.017	.110	.898[b]
	Residual	.940	6	.157		
	Total	.974	8			
a. Dependent Variable: Ln(Ut+1 /Ut						
b. Predictors: (Constant), (Et + Et+1)/2, (Ut + Ut+1)/2						

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.297	1.402		.212	.839
	(Ut + Ut+1)/2	-.526	2.096	-.255	-.251	.810
	(Et + Et+1)/2	-3.632E-005	.000	-.393	-.386	.713
a. Dependent Variable: Ln(Ut+1 /Ut						

Model Walter - Hilborn

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.625[a]	.391	.188	.23701636
a. Predictors: (Constant), Et, Ut				

ANOVA[a]

Model	Sum of Squares	df	Mean Square	F	Sig.

1	Regression	.216	2	.108	1.926	.226[b]
	Residual	.337	6	.056		
	Total	.553	8			

a. Dependent Variable: (Ut+1 + Ut) – 1
b. Predictors: (Constant), Et, Ut

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.617	.882		1.835	.116
	Ut	-2.358	1.206	-1.657	-1.954	.098
	Et	.000	.000	-1.592	-1.878	.110

a. Dependent Variable: (Ut+1 + Ut) – 1

Model CYP

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.923[a]	.851	.802	.23507945

a. Predictors: (Constant), (Et + Et+1), Ln Ut

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.899	2	.949	17.179	.003[b]
	Residual	.332	6	.055		
	Total	2.230	8			

a. Dependent Variable: Ln (Ut+1)
b. Predictors: (Constant), (Et + Et+1), Ln Ut

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.367	.198		-1.850	.114
	Ln Ut	-.259	.376	-.236	-.687	.517
	(Et + Et+1)	-7.871E-005	.000	-1.126	-3.277	.017

a. Dependent Variable: Ln (Ut+1)

Appendix-2
Validation of surplus production models of bonito data

Years	C_t (tons)	E_t (trips)	Validation: Abs($\frac{C_t - \hat{C}_t}{C_t}$)				
			Schaefer	Fox	Schnute	Walter- Hilborn	CYP
2003	1,625.8	2931	0.05136	0.05338	0.34666	0.06996	0.21907
2004	1,778.3	3444	0.01813	0.04036	0.36669	0.05484	0.28556
2005	1,847.3	3513	0.04078	0.06501	0.38719	0.07904	0.25916
2006	1,941.0	2800	0.23384	0.23124	0.46418	0.24554	0.01996
2007	1,847.0	6825	0.49399	0.46457	0.60188	0.48373	0.37726
2008	1,951.8	8296	0.38238	0.21722	0.96691	0.04549	1.32234
2009	1,958.2	8246	0.37744	0.21277	0.98175	0.04291	1.30589
2010	2,215.7	8496	0.21836	0.07356	0.91724	0.18055	1.07649
2011	2,245.8	12096	0.01498	0.00397	0.45415	0.90183	1.44751
2012	2,327.6	16468	0.13519	0.19531	3.04449	0.55067	1.46648
Rataan	**1,973.85**	**7,313**	**0.19664**	**0.15574**	**0.85311**	**0.26546**	**0.77797**

1. Model Schaefer : $\hat{C}_t = 0{,}636 E_t - 0{,}00003746 E_t^{\,2}$

2. Model Fox : $\hat{C}_t = E_t . e^{(-0{,}313 - 0{,}000113\, E_t)}$

3. Model Schnute : $\hat{Y} = a - b\,X_1 - c\,X_2 = 0{,}297 - 0{,}526\,X_1 - 0{,}000363\,X_2$ r = a = 0,297 q = c = 0,0000363 b = $\frac{r}{Kq} = 0{,}526$, K = $\frac{r}{bq} = \frac{0{,}297}{(0{,}526)(0{,}0000363)} = 15554{,}79$, $\hat{C}_t = Kq\,E_t - \frac{Kq^2}{r} E_t^{\,2}$ = 0,56464 E_t - 0,000069 E_t^2

4. Model Walter – Hilborn : $\hat{Y} = a - b\,X_1 - c\,X_2 = 1{,}617 - 2{,}358\,X_1 - 0{,}000128\,X_2$, r = a = 1,617 q = c = 0,000128 b = $\frac{r}{Kq} = 2{,}358$, K = $\frac{r}{bq} = \frac{1{,}617}{(2{,}358)(0{,}000128)} = 5357{,}43$, $\hat{C}_t = Kq\,E_t - \frac{Kq^2}{r} E_t^{\,2}$ = 0,67504 E_t - 0,0000543 E_t^2

5. Model CYP : $\hat{Y} = a + b\,X_1 - c\,X_2 = -0{,}367 - 0{,}259\,X_1 - 0{,}00007871\,X_2$, $r = \frac{2(1-b)}{1+b} = \frac{2(1+0{,}259)}{1-0{,}259} = 3{,}39811$

$q = -c\,(2-r) = -0{,}00007871(2 - 3{,}39811) = 0{,}00011$ $Q = \frac{a(2+r)}{2r} = \frac{-0{,}367(2+3{,}39811)}{2(3{,}39811)} = -0{,}29150$,

$K = \frac{e^{Q}}{q} = \frac{e^{-0{,}29150}}{0{,}00011} = 6792{,}20$, $\hat{C}_t = Kq\,E_t - \frac{Kq^2}{r} E_t^{\,2}$ = 0,74714 E_t - 0,0000242 E_t^2