J. Mar. Biol. Ass. India, **50** (2) : 139 - 148, July - December 2008

Estimation of variance components in the marine fish landings data by the method of nested analysis

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Abstract

The estimate of marine fish landings has been used as a principal source of information for fisheries management. For evolving viable management options, marine fish landings need to be estimated with greater precision. For this estimate of variance of the estimated landings is essential. In this paper we propose a method of estimating the true variance of the estimate of the average landings per month together with the variance due to each of the major factors contributing to the total variation.

Keywords: ANOVA, marine fish landings, multistage sampling, nested analysis, random effect model, variance estimation

Introduction

An essential requirement of any survey is to provide a measure of precision for each estimate derived from the survey data. It is well known that in almost all kinds of random sampling, the sample mean (total) is an unbiased estimator of the population mean (total). However, without a valid estimator of its variance, no reliable inferences can be made. Estimation of variance is a main concern in most of the cases. The problem becomes more complex as the sampling scheme involves several stages and different sampling rules are adopted at different stages. Though the analysis of variance (ANOVA) technique is one of the standard procedures to be adopted to compute the variances, the special nature of the data sometimes does not yield to the traditional computation of the sum of squares. For complicated multistage data, special procedures are to be adopted.

The sampling methodology currently adopted by the Central Marine Fisheries Research Institute (CMFRI) to estimate the marine fish landings in Kerala is based on a stratified two stage sampling scheme, the stratification is done over space and time. A combination of landing centre and day (landing centre day) constitute the primary stage units (PSU). The fishing boats that land on a landing centre day forms the secondary stage units (SSU). The details of the sampling design are described by Srinath *et al*. (2005). The fish landings data is highly fluctuating and the variations may be due to each of the stages of the survey and the selection process adopted at each stage. The existing procedure of computing the variability in the estimate of the fish landings takes into account only the between- day variation. The CMFRI fishery survey data may be regarded as a survey involving as many as 3 stages. In stage 1, combining the landing centres and days of the month, a one dimensional structure is imagined and simple random sampling is applied to select the landing centre days. In stage 2, though all the gear types operated on a day are observed, when we take the month as a whole it is quite likely that a few of the gear types remain unobserved. Hence, assuming that T boat types operate in every month, T_i are observed on the i^{th} selected day, Stage 2 also can be regarded as involving a selection of T_i boat types out of T. Stage 3 is the selection of the boats which is done in a semi-random manner. Thus the fish landings data collected for about 6 to 9 days in a month in a zone is a three-stage completely mixed structure from which the sum of squares cannot be extracted in the traditional way. In this paper, the nested model technique is applied to estimate the components of variance due to each stage of sampling in the marine fish landings data.

Material and methods

Nested data: Hierarchical or nested data arise very often in multistage sampling. In the multistage sample surveys, the entire area under the survey is divided into a large number of groups denoted by, say, z_1. Each of these z_1 groups, sub-divided into a large number of smaller groups, z_2, each of which in turn are split up into still smaller groups z_3 and so on until one arrives at the ultimate unit of sampling. The procedure that had been followed by first selecting a number of z_1 groups from the population and from each of these selected z_1 groups, selecting a number of z_2 groups, from each of the selected z_2 groups again a number of z_3 groups are chosen and so on until the ultimate units of sampling are reached, has been termed nested sampling by P. C. Mahalanobis (Ganguli, 1941). A nested design is said to be balanced if the number of subclasses at the h^{th} stage are the same for all the $(h-1)^{th}$ stage classes. In a multi stage sampling, balanced design refers to the case of the h^{th} stage units are of equal size. Otherwise the nested design is said to be unbalanced. Ganguli (1941) was the first to give a detailed description of the algebraic calculation of expectations of Mean Sum of Squares for the nested designs and estimation of variance components.

The general s-stage unbalanced nested random effect model: Consider a s-stage nested design with I_h subclasses at level h, h = 1,2,.., s + 1.
The model for an arbitrary s-level nested unbalanced design can be written as

$$Y_{i_1 i_2 i_3 \ldots i_{s-1} i_s i_{s+1}} = \mu + \alpha_1 + \beta_{2(1)} + \gamma_{3(2)} + \ldots + \xi_{s-1(s-2)} + \eta_{s(s-1)} + \varepsilon_{s+1(s)} \quad \ldots\ldots\ldots(1)$$

where $Y_{i_1 i_2 i_3 \ldots i_{s-1} i_s i_{s+1}}$ is the observation corresponding to the i_{s+1}^{th} (ultimate) unit in the I_{s+1}^{th} class within the I_s^{th} class within the I_{s-1}^{th} class etc., $i_h = 1,2,\ldots,I_h$, $h = 1,2,\ldots,s+1$.

μ is the overall mean effect,

α_1 is a vector of I_1 components representing the effect of classes at level 1,

$\beta_{2(1)}$ is a vector of I_2 components representing the effect of I_2 classes at level 2,

$\gamma_{3(2)}$ is a vector of I_3 components representing the effect of I_3 classes at level 3,

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$\xi_{s-1(s-2)}$ is a vector of I_{s-1} components representing the effect of I_{s-1} classes at level s-1,

$\eta_{s(s-1)}$ is a vector of I_s components representing the effect of I_s classes at level s and $\varepsilon_{s+1(s)}$ is a vector of I_{s+1} components representing the residual effect. I_1

The following assumptions are made:

(i) μ is a fixed effect,

(ii) α_1, $\beta_{2(1)}$, $\gamma_{3(2)}$,...,$\eta_{s(s-1)}$ are the random effects, each normally distributed with mean 0 and variance σ_1^2, σ_2^2,....,σ_s^2 respectively,

(iii) $\varepsilon_{s+1(s)}$ are independent identically distributed normal random variable with mean 0 and variance σ_{S+1}^2,

(iv) the effects of the various levels are independent and homoscedastic.

In the following section, we apply the technique of nested design to estimate the variance components due to the different stages in fish landings data.

Nested analysis of fishery data: Fig.1 is a schematic of nested structure of marine fish landings data in India. The country is divided into different states. Each state is divided into several

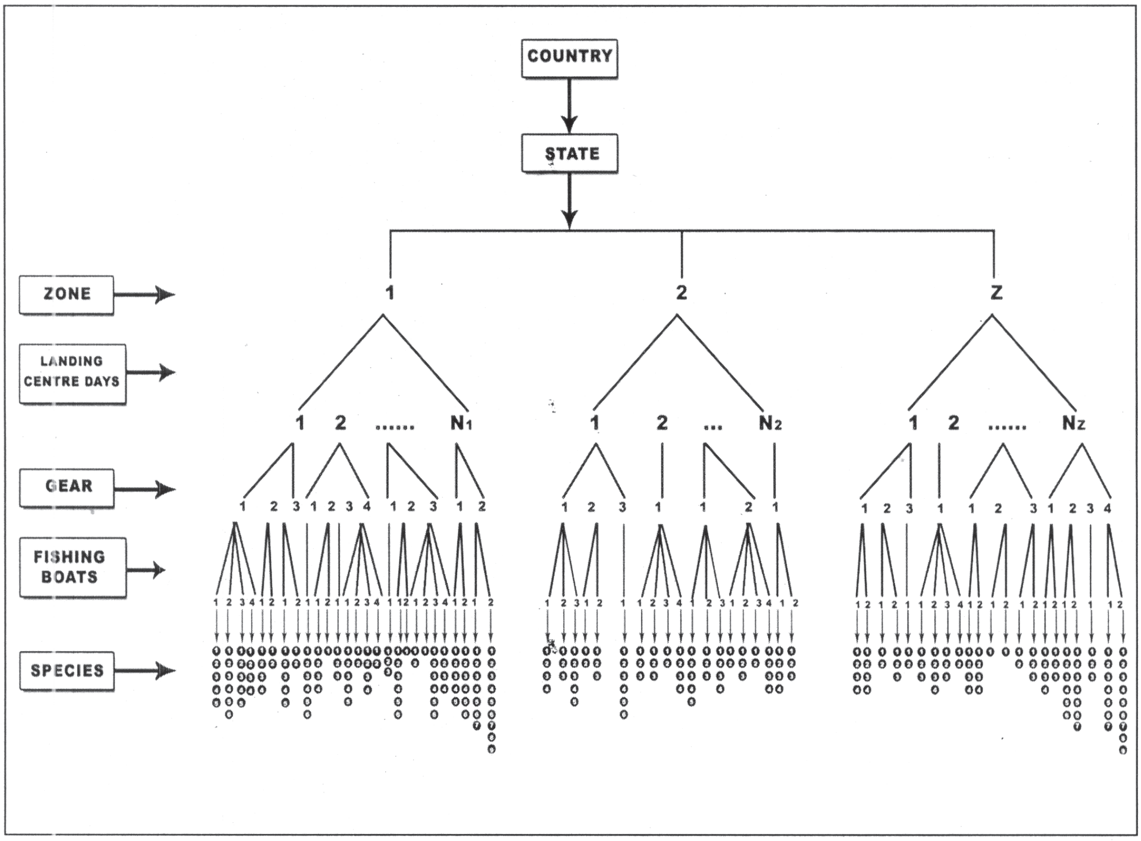

Fig. 1. Nested structure of marine fish landings data

zones. Only one of the state is considered in the Fig. 1. Since the states and zones are considered independently and identically, nesting is considered from landing centre days onwards only.

Zone is taken as 0-level,

Landing centre day within zone – level 1. (A zone consists of N landing centres each operating for D days in a month thus there are ND landing centre days out of which n are selected)

Gear type – level 2, T_i, gears operated on the i^{th} day.

Boats of gear type j – level 3. M_{ij} boats of type j landed on the i^{th} day out of which M_{ij} boats observed.

Species landed – level 4 (ultimate units).

In the sampling plan of CMFRI, the landing centre day forms the first stage units and boats are the second stage units. Since multiple gears are operating in a landing centre day, the sampling of boats are done for each gear.

The three level nested model is

$$Y_{i_1 i_2 i_3 i_4} = \mu + \alpha_1 + \beta_{2(1)} + \gamma_{3(2)} + \varepsilon_{4(3)} \quad ....(2)$$

$i_1 = 1,2...,n;\ i_2 = 1,2...,T_{i_1};\ i_3 = 1,2...,\ M_{i_1 i_2};\ i_4 = 1,2...,\ n_{i_1 i_2 i_3}$

where $Y_{i_1 i_2 i_3 i_4}$ is the quantity of fish of the i_4^{th} species landed by the i_3^{th} fishing boat belonging to the i_2^{th} fishing gear on the i_1^{th} landing centre day, $n_{i_1 i_2 i_3}$ denotes the number of species observed in the i_3^{th} boat of the i_2^{th} gear type on i_1^{th} landing centre day.

Comparing with the general model (1) we have, $I_1=n,\ I_2=T_{i_1},\ I_3=M_{i_1 i_2}$ and $I_4=n_{i_1 i_2 i_3}$.

μ is the overall mean effect,

α_1 is a vector of n components representing the landing centre day effect,

$\beta_{2(1)}$ is a vector of I_2 components representing the gear effect,

$\gamma_{3(2)}$ is a vector of I_3 components representing the boat effect,

and $\varepsilon_{4(3)}$ is a vector of I_4 components representing the residual effect.

The species and their quantity caught varies with respect to landing centre days, type of gear used, fishing units used, duration of fishing hours, depth in which gear was operated, time of fishing operation, climatic conditions etc. Hence, all the terms in the model (except μ) are assumed to be random variables. All the parameters are subjected to the assumptions under model (2).

Results

Using the nested model (2) described above, the analysis of the CMFRI fish landings data for average catch over the 15 fishing zones (K1 to K15) of the state of Kerala are made for the three year period from 2004 to 2006. The analysis was done using the 'nested procedure' and 'variance component procedure' in the Statistical Analysis System package. The 'nested procedure' performs a random-effects analysis of variance which is appropriate for a multistage nested sampling design. Rather than estimating the true variances due to each level by eliminating all the negative estimates, our objective here is to get an idea about the percentage contribution of each level to the total variance in each zone for each month. Due to paucity of space only the minimum representative outputs necessary for establishing our objective are included. Table 1 shows the ANOVA table corresponding to zone K1 for the year 2006. The last two columns of this table indicate the estimate of the variance components due to each level and its percentage share to the total variance. From the table, it could be seen that variance estimates are negative for many cases. Though the nested method is theoretically very sound, in several practical cases, it provides negative values as the estimate for the variance components causing difficulty in interpretation and decision making. The frequent occurrence of negative estimates for one or more of the variance components had limited the usefulness of the nested ANOVA. The problem of negative estimates of variance components has received a lot of attention in the literature (Nelder, 1954; Thompson, 1962; Anderson, 1965; Federer, 1968). It occurs due to the fact that the variability at a higher level is less than the variability at a smaller level, resulting in a negative estimate of variance (Fletcher and Underwood, 2002).

There have been several efforts to cope with the phenomenon of negative estimates of variance components. Ganguli (1941) suggested considering the negative estimate of variance as zero. Herbach (1959) used the maximum likelihood principle to obtain variance component estimators, which are non-negative. The maximum likelihood estimates are not generally unbiased but they often have smaller variance than the unbiased estimators. Thompson (1962) used the restricted maximum likelihood (REML) estimation procedure for balanced data which yields non-negative estimates, by assuming the model to be correct.

In the present study, the cases of all negative estimates of variances are taken as zero. From Table 1, it was found that the estimate of variance due to day is zero for all the months and that due to boats, it is zero except for three months. In the three non-zero cases, the percentage share was 17% in March, 11% in May and only 1% in July. The major shares of variation were due to gears and residual. The gear variation is as high as 67% in March and the residual variation is as high as 69% in September. Table 1 indicates that the variation in the fish landings data is mainly due to gear-wise and residual variations while the contribution due to day-wise and boat-wise variations are negligible.

Table 1. Analysis of variance for the marine fish landings data for zone K1 during 2006

Month	Source of variation	*D.F.	Sum of squares	Mean sum of squares	Variance Estimate	components Percentage
January	Day	4	463.2	115.8	-12.5	0
	Gear	20	10301.0	515.0	47.0	51
	Boat	101	3058.9	30.3	-6.1	0
	Residual	168	7465.8	44.4	44.4	49
	Total	293	21289.0	72.7	91.5	100
February	Day	3	2615.6	871.9	-48.0	0
	Gear	14	29126.0	2080.4	188.2	63
	Boat	71	8656.3	121.9	9.5	3
	Residual	126	12538.0	99.5	99.5	33
	Total	214	52936.0	247.4	297.2	100
March	Day	5	40026.0	8005.3	-443.0	0
	Gear	16	317894.0	19868.0	1735.1	67
	Boat	104	134821.0	1296.4	443.9	17
	Residual	131	54607.0	416.8	416.8	16
	Total	256	547348.0	2138.1	2595.8	100
April	Day	3	1559.5	519.8	-288.8	0
	Gear	11	141491.0	12863.0	950.6	38
	Boat	66	53837.0	815.7	-311.2	0
	Residual	119	185591.0	1559.6	1559.6	62
	Total	199	382479.0	1922.0	2510.1	100
May	Day	30	4923.7	1641.2	-7.5	0
	Gear	9	12913.0	1434.8	117.7	35
	Boat	61	15116.0	247.8	37.0	11
	Residual	72	12746.0	177.0	177.0	53
	Total	145	45699.0	315.2	331.7	100
June	Day	30	1043.7	347.9	-90.6	0
	Gear	6	17347.0	2891.1	174.4	35
	Boat	37	6966.7	188.3	-39.1	0
	Residual	112	35550.0	317.4	317.4	65
	Total	158	60907.0	385.5	491.8	100
July	Day	4	9174.7	2293.7	-349.1	0
	Gear	17	215789.0	12693.0	1157.7	65
	Boat	90	60039.0	667.1	26.1	1
	Residual	146	88755.0	607.9	607.9	34
	Total	257	373758.0	1454.3	1791.7	100
August	Day	30	31885.0	10628.0	-3478.4	0
	Gear	15	2370642.0	158043.0	12534.0	39
	Boat	63	684944.0	10872.0	-3051.1	0
	Residual	160	3143872.0	19649.0	19649.0	61
	Total	241	6231343.0	25856.0	32183.0	100
September	Day	4	296266.0	74067.0	-1124.0	0
	Gear	13	1633701.0	125669.0	10691.0	31
	Boat	59	602399.0	10210.0	-5550.0	0
	Residual	118	2857441.0	24216.0	24216.0	69
	Total	194	5389807.0	27783.0	34906.0	100
October	Day	3	5999.6	1999.9	-23.8	0
	Gear	12	27794.0	2316.2	174.0	36
	Boat	75	12657.0	168.8	-60.7	0
	Residual	131	40963.0	312.7	312.7	64
	Total	221	87415.0	395.5	486.7	100
November	Day	3	2299.6	766.5	-45.1	0
	Gear	12	27072.0	2256.0	178.9	31
	Boat	63	14278.0	226.6	-68.7	0
	Residual	121	48338.0	399.5	399.5	69
	Total	199	91988.0	462.3	578.4	100
December	Day	3	4465.8	1488.6	-13.4	0
	Gear	10	17030.0	1703.0	113.0	34
	Boat	69	10870.0	157.5	-25.2	0
	Residual	128	28154.0	220.0	220.0	66
	Total	210	60520.0	288.2	333.0	100

*D.F. refers to degrees of freedom

Table 2a. The monthly estimate of average landings (kg per day) and the standard error for the zones K1 and K2 during the year 2006

Month	K1						K2					
	$\hat{Y}$	S.E($\hat{Y}$)	Percentage of total variance				$\hat{Y}$	S.E($\hat{Y}$)	Percentage of total variance			
			Day	Gear	Boat	Residual			Day	Gear	Boat	Residual
Jan.	8.0	0.6	0	51	0	49	10.3	1.4	0	38	9	53
Feb.	12.2	1.7	0	63	3	33	13.4	3.7	2	28	0	70
Mar.	24.6	4.8	0	67	17	16	45.5	27.3	3	14	0	83
Apr.	22.9	0.0	0	38	0	62	30.9	41.5	42	2	0	56
May	17.5	3.4	0	35	11	53	25.4	11.2	29	20	13	38
Jun.	14.8	0.0	0	35	0	65	26.7	3.5	0	36	0	54
Jul.	23.0	0.0	0	65	1	34	264.0	165.6	61	0	0	39
Aug.	64.0	0.0	0	39	0	61	273.5	68.9	0	51	0	49
Sep.	60.5	24.3	0	31	0	69	153.9	87.1	6	45	5	44
Oct.	16.6	2.9	0	36	0	64	31.2	9.4	14	0	0	86
Nov.	14.3	2.2	0	31	0	69	16.8	2.0	1	6	2	91
Dec.	14.3	2.8	0	34	0	66	24.4	0.0	0	59	0	41

Table 2b. The monthly estimate of average landings (kg per day) and the standard error for the zones K3 and K4 during the year 2006

Month	K3						K4					
	$\hat{Y}$	S.E($\hat{Y}$)	Percentage of total variance				$\hat{Y}$	S.E($\hat{Y}$)	Percentage of total variance			
			Day	Gear	Boat	Residual			Day	Gear	Boat	Residual
Jan.	14.5	6.7	0	35	0	65	59.7	0.0	0	79	14	7
Feb.	10.6	3.1	0	63	0	37	133.7	54.1	0	80	0	20
Mar.	16.4	5.1	8	21	0	71	168.0	233.2	18	66	11	5
Apr.	42.0	12.1	3	8	0	89	52.7	88.5	0	99	1	0
May	30.4	13.5	17	1	0	82	26.9	23.7	0	60	37	3
Jun.	17.4	5.0	0	31	0	69	201.6	0.0	0	89	1	10
Jul.	28.6	10.9	0	44	0	56	172.6	60.7	0	73	0	27
Aug.	31.5	39.2	54	0	10	36	332.4	80.8	1	26	0	73
Sep.	29.8	10.3	4	16	0	80	267.4	31.4	0	78	0	22
Oct.	23.1	16.8	6	30	0	64	74.9	0.0	0	81	5	14
Nov.	8.6	7.6	53	1	0	46	46.8	0.0	0	89	1	10
Dec.	18.2	15.1	10	11	0	79	81.7	35.6	0	91	1	8

Since Table 1 is a typical representative of all other zones for the three years of analysis, the other ANOVA tables are not included. Instead, tables indicating the average landings / species / gear / boat / day and its standard error and the percentage variation due to each level as given by the ANOVA table are given in Tables 2 a to 2 h for each zone for the year 2006. The months in which more than 10% contribution to the variation are observed due to days and boats for each zone as from the respective ANOVA tables for the three years are presented in Table 3. This table reveals that out of the 540 cases (15 × 12 × 3) of study, only 13% exhibited more than 10% variance

Table 2c. The monthly estimate of average landings (kg per day) and the standard error for the zones K5 and K6 during the year 2006

Month	K5						K6					
	$\hat{Y}$	S.E($\hat{Y}$)	Percentage of total variance				$\hat{Y}$	S.E($\hat{Y}$)	Percentage of total variance			
			Day	Gear	Boat	Residual			Day	Gear	Boat	Residual
Jan.	3.5	1	0	15	0	85	294.4	528.7	72	15	7	6
Feb.	4.9	5.4	0	76	8	16	309.4	279.7	0	75	20	5
Mar.	5.6	2.9	8	0	0	92	101.6	84.6	0	78	11	11
Apr.	3.3	0.0	0	0	7	93	310.3	233.0	0	87	0	13
May	4.6	0.0	0	0	0	100	124.4	107.9	0	87	8	5
Jun.	30.3	133.8	0	100	0	0	113.6	106.6	28	5	0	67
Jul.	123.9	291.0	84	2	14	0	2412.6	1396.0	60	11	29	0
Aug.	2.0	0.4	8	0	0	92	1396.2	528.4	0	69	4	27
Sep.	2.4	0.4	0	22	0	78	1482.7	483.5	0	72	9	19
Oct.	6.3	1.3	0	0	31	69	572.0	549.6	83	0	8	9
Nov.	125.6	1700.6	98	2	0	0	214.0	448.3	0	94	4	2
Dec.	3.8	1.1	8	2	0	90	87.0	145.8	0	94	1	5

Table 2d. The monthly estimate of average landings (kg per day) and the standard error for the zones K7 and K8 during the year 2006

Month	K7						K8					
	$\hat{Y}$	S.E($\hat{Y}$)	Percentage of total variance				$\hat{Y}$	S.E($\hat{Y}$)	Percentage of total variance			
			Day	Gear	Boat	Residual			Day	Gear	Boat	Residual
Jan.	145.2	757.7	0	98	2	0	111.9	57.3	0	82	2	16
Feb.	66.8	15.8	0	7	0	93	109.0	85.9	0	77	16	7
Mar.	109.6	0.0	0	88	11	1	64.5	9.0	0	46	5	49
Apr.	283.5	346.7	34	0	0	66	90.5	42.9	0	59	0	41
May	78.1	73.4	17	56	0	27	112.0	36.8	0	75	7	18
Jun.	401.6	745.9	43	34	15	8	149.6	44.8	0	46	1	53
Jul.	22.1	0.0	0	25	0	75	90.9	0.0	0	92	5	3
Aug.	2.4	0.5	15	0	0	85	130.5	65.9	0	32	0	68
Sep.	140.6	235.0	89	0	11	0	203.3	73.6	0	64	5	31
Oct.	120.8	287.8	0	98	2	0	295.5	95.6	0	39	9	52
Nov.	71.6	164.7	88	0	0	12	76.7	35.2	0	54	4	42
Dec.	58.6	198.2	62	0	7	31	72.1	0.0	0	67	1	32

contribution due to days and boats. The zones K2, K5, K6 and K7 indicated more than 25% contribution due to day variation, while zones K6 and K12 indicated more than 25% contribution due to boat variation. Tables 2 a to 2 h indicate that there are only a very few cases in which the contribution of the variation due to gears is less than 10%. The total number of such cases among the study cases is found to be less than 7%.

Discussion

In the present study, the estimate and its variance of average landings / species/ gear/ boat / day for each zone-month stratum was found out using the three stage nested random effect model.

Table 2e. The monthly estimate of average landings (kg per day) and the standard error for the zones K9 and K10 during the year 2006

Month	K9						K10					
	$\hat{Y}$	S.E($\hat{Y}$)	Percentage of total variance				$\hat{Y}$	S.E($\hat{Y}$)	Percentage of total variance			
			Day	Gear	Boat	Residual			Day	Gear	Boat	Residual
Jan.	161.7	94.7	0	75	1	24	96.5	292.6	0	98	0	2
Feb.	127.6	104.2	0	98	1	1	43.7	0.0	0	95	0	5
Mar.	80.7	30.1	0	62	19	19	11.9	3.0	7	0	0	93
Apr.	116.4	172.6	0	73	4	23	14.1	6.5	0	67	0	33
May	283.8	0.0	0	97	1	2	85.2	0.0	0	75	3	22
Jun.	84.1	29.6	0	17	0	83	27.4	2.8	0	0	0	100
Jul.	227.7	180.5	0	94	3	3	55.8	38.4	29	0	0	71
Aug.	9.7	3.8	0	25	0	75	12.3	97.6	100	0	0	0
Sep.	346.5	176.6	0	73	0	27	62.3	13.8	0	0	0	100
Oct.	280.1	0.0	0	94	3	3	295.5	95.6	0	39	9	52
Nov.	59.3	0.0	0	87	1	12	17.5	5.4	9	0	0	91
Dec.	34.1	6.4	0	5	0	95	36.0	32.2	0	88	1	11

Table 2f. The monthly estimate of average landings (kg per day) and the standard error for the zones K11 and K12 during the year 2006

Month	K11						K12					
	$\hat{Y}$	S.E($\hat{Y}$)	Percentage of total variance				$\hat{Y}$	S.E($\hat{Y}$)	Percentage of total variance			
			Day	Gear	Boat	Residual			Day	Gear	Boat	Residual
Jan.	115.3	29.1	0	87	1	12	95.4	16.6	0	54	9	37
Feb.	117.5	34.9	0	71	8	21	162.4	40.2	0	60	8	32
Mar.	114.9	0.0	0	71	2	27	95.8	13.5	0	38	40	22
Apr.	141	25.0	0	68	1	31	65.7	9.2	0	57	9	34
May	9	38.1	0	65	7	28	50.8	13.9	6	8	4	82
Jun.	138.5	50.6	0	92	2	6	140.5	39.6	0	38	32	30
Jul.	99.7	38.4	29	0	0	71	55.8	38.4	29	0	0	71
Aug.	279.0	88.6	0	39	11	50	197.7	22.4	0	20	0	80
Sep.	170.1	0.0	0	70	0	30	108.3	30.9	0	16	34	50
Oct.	150.3	46.2	0	74	0	26	168.7	29.8	0	30	13	57
Nov.	83.5	30.0	0	55	0	45	116.9	21.6	0	24	23	53
Dec.	85.6	14.3	0	70	3	27	102.3	30.9	0	64	5	31

The estimate of variance provided by the nested model accounts the variability at each stage of the design. Further, the proportion of total variance accounted at each level in the fish landings data was computed. The marine fisheries resources are dynamic and subject to fluctuations due to fishery dependant as well as fishery independent factors. Similarly, the fish landings also vary with respect to the above factors. The variation between boats was due to the difference in the fishing effort, fishing capacity of the boat, the type of resources exploited, fishing ground in which the boat was operated etc.

A variety of craft and gear operate in each zone, resulting in wide variation between the landings. The between-gear variation was due to

Table 2g.The monthly estimate of average landings (kg per day) and the standard error for the zones K13 and K14 during the year 2006

	K13						K14					
Month	$\hat{Y}$	S.E($\hat{Y}$)	Percentage of total variance				$\hat{Y}$	S.E($\hat{Y}$)	Percentage of total variance			
			Day	Gear	Boat	Residual			Day	Gear	Boat	Residual
Jan.	67.4	10.4	0	72	7	21	140.9	20.8	0	34	0	66
Feb.	149.1	84.1	0	94	3	3	153.6	281.6	0	1	9	20
Mar.	215.0	57.3	0	87	2	11	131.4	24.7	0	31	0	69
Apr.	70.9	0.0	0	69	0	31	224.1	50.5	0	34	0	66
May	138.6	23.8	0	35	0	65	263.0	21.5	0	60	0	40
Jun.	183.1	24.1	0	80	0	20	280.7	65.8	0	41	0	59
Jul.	712.8	660.5	0	92	4	4	634.4	415.1	0	67	25	8
Aug.	213.9	0.0	0	73	0	27	550.0	249.3	0	89	0	11
Sep.	172.0	57.0	0	59	2	39	385.3	1277.7	0	92	0	8
Oct.	164.0	17.0	0	80	5	15	256.7	204.9	0	33	0	67
Nov.	150.4	23.3	0	67	11	22	90.5	51.8	0	16	0	84
Dec.	99.9	0.0	0	73	3	24	109.8	37.8	0	11	0	89

Table 2h.The monthly estimate of average landings (in kg.) per day and the standard error for the zone K15 during the year 2006

	K15					
Month	$\hat{Y}$	S.E($\hat{Y}$)	Percentage of total variance			
			Day	Gear	Boat	Residual
Jan.	108.7	38.0	0	58	4	32
Feb.	181.9	48.4	0	80	3	17
Mar	171.7	56.5	0	24	23	53
Apr.	167.7	43.0	0	18	0	82
May	273.0	104.1	0	18	0	82
Jun.	318.7	87.0	0	37	0	63
Jul.	1268.6	0.0	0	83	9	8
Aug.	447.2	475.5	78	0	6	16
Sep.	509.6	118.2	0	14	0	86
Oct.	331.8	0.0	0	43	9	48
Nov.	150.0	25.6	0	58	7	35
Dec.	70.0	22.7	0	25	0	75

the different type of gears operated in the selected day. The between-days variation was mainly due to the presence or absence of one or the other types of craft landed. Since there is a lot of variation between the type of gear used, it is necessary to sample more number of each type of fishing units on the selected day.

The nested analysis reveals that the total variance of the fish landing data is the sum of variation at each level-between days, gears, boats and the residual. The magnitude of contribution at each level may differ depending on factors such as the seasonality, climatic conditions, fishing practices etc. Hence, the component-wise contributions of variance must be taken into account for analysing the data of each zone every month. Further, it is observed that the major contribution to the variance is always due to gear types. Hence, any analysis of the data should essentially take into account the variation due to gear types. However, for simplicity of analysis, ignoring between-days and between-boats variation may not cause very high discrepancy in most of the cases. In cases where between day-variation is comparatively high, it is necessary to observe more number of days. Wherever between-boats variations are high, the boats may be stratified according to the fishing effort and capacity.

Acknowledgements

The authors wish to express sincere gratitude to the Director, CMFRI for providing necessary facilities for the study. The second author is grateful to Ministry of Statistics and Programme Implementation, Government of India for the award of doctoral fellowship during the study.

Table 3. Months exhibiting more than 10% variation due to days and boats

Zone	Day variation >= 10%			Boat variation >= 10%		
	2004	2005	2006	2004	2005	2006
K1	-	-	-	Apr.	Mar.	Mar. May
K2	Jan. Jul. Oct.	Jul. Nov.	Apr. May Jul. Oct.	-	Mar.	May
K3	Mar. May Jun. Sept.	Jan. Feb. Mar. Nov.	May Aug. Nov. Dec.	-	-	Aug.
K4	May, Oct.	Jan.	Mar.	-	-	Jan. Mar. May
K5	Apr. May Jun. Aug.	Jan. Feb. Jul. Sept.	Jul. Nov.	Jan.	Oct. Dec.	Jul. Oct.
K6	Apr. May Sept. Oct.	Mar. Dec.	Jan. Jun. Jul. Oct.	Mar. May Oct.	Jan. Mar. Sept. Oct.	Feb. Mar. Jul.
K7	Jan. Jul. Nov.	Jul. Nov.	Apr. May Jun. Aug. Sept. Nov. Dec.	Sep. Nov.	Jun. Nov.	Mar. Jun. Sept.
K8	Jul. Dec.	Sept.	-	Apr. Dec.	Jan. Mar.	Feb.
K9	-	-	-	Jan.	-	Mar.
K10	Jan. Nov.	-	Jul. Aug.	-	Aug.	-
K11	-	-	-	-	Jan.	Aug.
K12	-	-	-	Feb. Mar. Apr. Dec.	Jan. Feb. Mar. Sep. Oct. Nov.	Mar. Jun. Sept. Oct. Nov.
K13	-	Mar.	-	Feb. Sep. Dec.	Jan. Feb. Sep. Oct.	Nov.
K14	-	-	-	-	Jul.	Jul.
K15	Feb.	Mar. Sept.	Aug.	Mar. Sept.	Jul. Sept.	Mar.

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Received: 28 October 2008
Accepted: 28 November 2008