# THE APPLICABILITY OF CLASSICAL BULK MODEL FOR ESTIMATING SALINITY STRATIFICATION OF CHOKED COASTAL LAGOONS IN SRI LANKA

Saitama University Student Member ○G. L. Perera
Saitama University Regular Member Eiichi Furusato
Saitama University Regular Member Norio Tanaka
University of Ruhuna Tilak Priyadarshana

## 1. INTRODUCTION

Developing a bulk model to estimate the salinity stratification status of coastal lagoons is important for Ecosystem engineering in terms of rehabilitation and restoration of coastal lagoons. This paper discusses on the applicability of Fischer's (1972) estuarine relative stratification model for choked coastal lagoons based on the field investigations conducted at two choked coastal lagoons in Sri Lanka.

## 2. METHODS

### 2.1 Field surveys

Out of nine choked coastal lagoons in Sri Lanka, which have been affected by anthropogenic activities, two lagoons were selected for the field surveys to investigate the salinity stratification status. The selection of the two lagoons was made based on lagoon representative assessment where a graphical comparison was made between two non dimensional parameters $W_M/L_M$ (the ratio of the lagoon mouth width to length) and $A_{CT}/A_L$ (the ratio of the total catchment area to surface area of the lagoon)(Fig 2.). Koggala Lagoon was selected to represent the lagoons with higher sea water influence while Rekawa Lagoon was selected to represent the lagoons with higher fresh water influence. Considered conditions for the field surveys of each lagoon are given in Table 1 with respective survey case names. During the field surveys, the vertical profiles of salinity, temperature and dissolved oxygen levels were measured at stations, longitudinally expanding throughout the lagoon. However, the salinity data measured at the survey stations representing the central part of each lagoon were only presented in this paper (Fig. 3 and 4). The salinity stratification characteristics of the two lagoons were qualitatively studied with respect to human alterations by Furusato et al. (2013).

**Table 1: Field survey conditions and survey case names**

| Lagoon | Season | Timing | Mouth | Case Name |
|---|---|---|---|---|
| Koggala | Rainy | 22Nov2011 | Opened | K22Nov11R |
| | | 30Nov2012 | Opened | K30Nov12R |
| | Dry | 16Mar2012 | Opened | K16Mar12D |
| | | 14Feb2013 | Opened | K14Feb13D |
| Rekawa | Rainy | 21Oct2012 | Opened | R21Oct12R-O |
| | Dry | 17Mar2012 | Closed | R17Mar12D-C |
| | | 27Jan2013 | Closed | R27Jan13D-C |

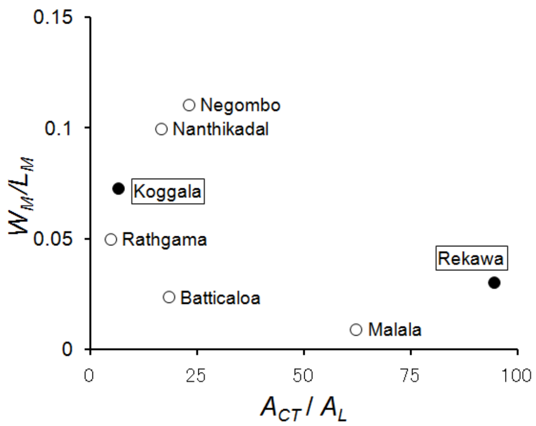


**Fig. 2: Representative assessment based on accessibility of sea water into lagoons and probable fresh water discharge.**

### 2.2 Bulk model analysis

Fischer (1972) developed a method to estimate the relative stratification ($\delta S/S$; the ratio of surface and bottom salinity difference to mean salinity of the considered cross section) of estuaries based on two bulk parameters; the Estuarine Richardson Number ($R_{iE}$) and Densimetric Froude Number ($F_m$) (Fischer 1972).

$$R_{iE} = \frac{(\Delta\rho/\rho_0)g(Q_f/b)}{U_t^3} \quad (1)$$

$$F_m = \frac{Q_f/bd}{\sqrt{gd(\Delta\rho/\rho_0)}} \quad (2)$$

**Table 2: Parameter value determination criteria for each lagoon. [*1]Gunaratne et al. (2011).**

| Symbol | Lagoon | | |
|---|---|---|---|
| | Koggala | Rekawa | |
| | Mouth opened | | Mouth closed |
| $b$ | Mouth entrance width | | Mean width of the lagoon mouth channel |
| $d$ | Mean depth at mouth | | Mean depth at mouth |
| $\rho_0$ | Density at sea | | Density at the bottom layer of the lagoon |
| $U_t$ [*2] | r.m.s tidal velocity [*1] | r.m.s tidal velocity | $\frac{Q_{runoff}}{a_m}$ |

[*2] $Q_{runoff}$; the surface runoff discharge. $a_m$; Cross sectional area of the lagoon mouth channel.

where $\Delta\rho$ is the density difference between freshwater and sea water, $g$ is the acceleration of gravity and $Q_f$ is inflow discharge. In estimating the monthly discharge, a linear relationship was assumed with the monthly rainfall (Gunaratne et

Keywords: Estuarine Richardson Number, bulk parameters, wind shear stress
Saitama University, 255 Shimo-Okubo, Sakura-Ku, Saitama TEL: 048-858-3561 E-mail：furusato@mail.saitama-u.ac.jp

al. 2011). Furthermore, the velocity and cross sectional area of the inflow stream surface layer were used to estimate the inflow freshwater discharge for Koggala Lagoon. Monthly fresh water discharge of Rekawa Lagoon was calculated based on monthly surface runoff discharge rates estimated by Gunaratne et al. (2010). The rest of the parameters included in $R_{iE}$ (Eq.1) and $F_m$ (Eq.2) were determined for each lagoon according to the Table 2.

## 3. RESULTS AND DISCUSSION

Fischer's diagrams (Fig 3 (a) & Fig. 4 (a) white & corresponding gray color plots) show that the estimated $\delta S/S$ values are over estimations with respect to observed values in dry season for both lagoons. Furthermore, the deviations of estimated values from observed values are relatively larger in all the dry season results. Conversely, there is a relatively good agreement in all the rainy season results for both lagoons (Fig.3 (a) & Fig.4 (a) black & correspond gray color plots).The reason for the larger deviations in estimated $\delta S/S$ values from the observed values in dry season would be due to the fact that the wind induced mixing is not accounted in $R_{iE}$ . More specifically, the surface shallow fresh (brackish) water layer, generated due to the lower amount of fresh water discharge in dry season, would be easily mixed by the wind stress. Therefore, a distinctive surface layer cannot be observed for both lagoons in dry season ((Fig.3 (b) & Fig.4 (b) white color plots). On the other hand, large amount of fresh water discharge in rainy season creates a deeper surface layer which could not be entirely broken by the wind. Hence, neglecting mixing induced by wind in $R_{iE}$ doesn't affect much on the estimated $\delta S/S$ values in rainy season. Thus , the estimated and observed $\delta S/S$ values show a relatively finer agreement in rainy season than in dry season. Modifying $R_{iE}$ including a factor to represent wind stress would increase the applicability of Fischer's model to choked coastal lagoons in Sri Lanka.

## 4. CONCLUSION

In this study, the applicability of Fischer's (1972) model to estimate salinity stratification of choked coastal lagoons in Sri Lanka was examined. Although the model provides good estimated results in rainy season, in dry season overestimation of $\delta S/S$ values were confirmed for two lagoons with contrasting characteristics of mouth shapes.

## 4. ACKNOWLEDGEMENT

This study was partly funded by JSPS Asia-Africa Science Platform Program, Japan and partly by Grant –in-Aid for Exploratory Research, Japan (No.25550007).

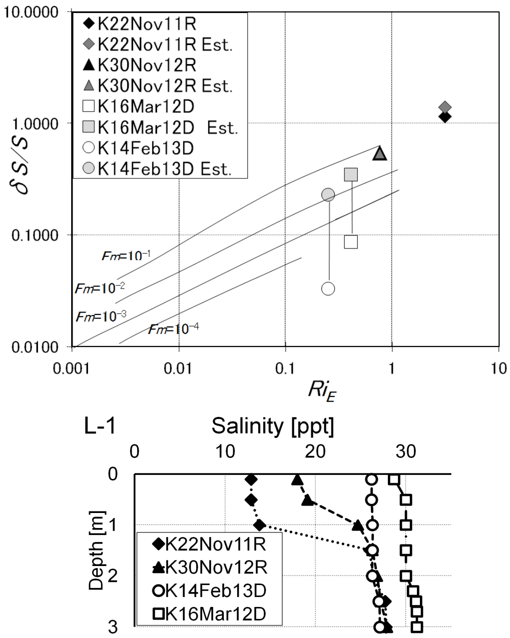


**Fig. 3: Salinity characteristics in Koggala Lagoon, (a) application of Fisher's model, (b) observed vertical salinity profiles at the central part. Legend entries ending with the abbreviation "Est." correspond to estimated results represented as gray color plots. White and black color plots represent dry and rainy season results, respectively**

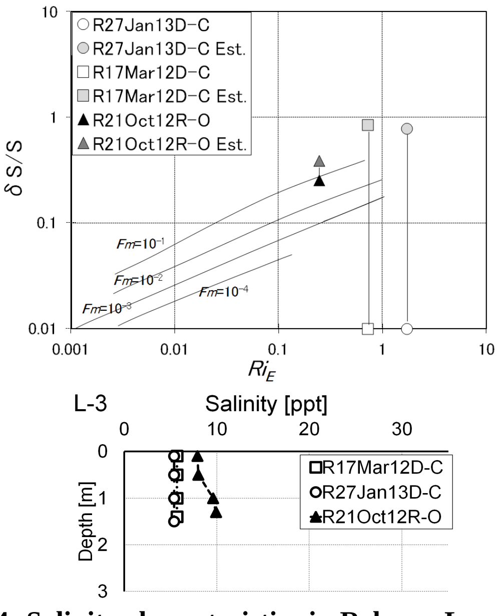


**Fig. 4: Salinity characteristics in Rekawa Lagoon, (a) Application of Fischer's model, (b) observed vertical salinity profiles at the central part. For legend, see the caption in Fig.3.**

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