The diurnal movement pattern of waterbirds in the Kukut area of Lake Songkla, southern Thailand

C A Galbraith[1], G J Pierce[4], C J Spray[2] & I H Robinson[3]

[1]Scottish Natural Heritage, 2 Anderson Place, Edinburgh EH6 5NP, United Kingdom
[2]Northumbrian Water Limited, Abbey Road, Pity Me, Durham, United Kingdom.
[3]Waltham Centre for Pet Nutrition, Freeby Lane, Waltham on the Wolds, Melton Mowbray, Leicestershire, LE14 4RS, United Kingdom.
[4]Department of Zoology, University of Aberdeen, Tillydrone Avenue, Aberdeen, AB24 2TZ, United Kingdom.

Daily movements by waterbirds, between roosting and feeding areas, were observed in the Thale Sap Non-Hunting area (Lake Songkla, southern Thailand) during summer and autumn 1987. Counts of birds in flight in the summer indicated the presence of more than 4500 Lesser Tree Ducks as compared to approximately 1000 ducks of all species in the autumn. In the autumn, approximately 2000 Little Egrets and Great Egrets and 500 Yellow Bitterns and Cinnamon Bitterns made regular use of a roost close to the lakeside village of Kukut and moved between this roost and feeding areas south of Kukut. Numbers of bitterns and egrets recorded in flight past Kukut peaked at dawn and dusk, whereas terns and ducks were seen throughout daylight hours. Egrets foraged on floating grassmats adjacent to Kukut. Analysis indicated temporary local depression of egret numbers due to the presence of fishermen working in and around the grassmats.

Keywords: Waterbirds, diurnal movements, Thailand, disturbance, conservation.

Lake Songkla is a shallow lagoon of fresh to brackish water, covering 1040 km² on the east coast of southern Thailand. An area of lake around the village of Kukut (Thale Sap; **Figure 1**) is designated as a Non-Hunting Area in recognition of its importance for resident and migratory birds (Anon., 1981, 1982; Jintanugool & Round, 1989). In 1987 the Non-Hunting Area or Kukut Sanctuary comprised 315 km², of which 160 km² were lake water. The National Environment Board (Anon. 1981) recorded the presence of 143 bird species, including 26 residents, of which the most abundant are Little Grebe *Tachybaptus ruficollis*, Cotton Teal *Nettapus coromandelianus*, Lesser Tree Duck *Dendrocygna javanica*, Moorhen *Gallinula chloropus*, Purple Gallinule *Porphyrio porphyrio*, Black-winged Stilt *Himantopus himantopus*, Yellow Bittern *Ixobrychus sinensis*, Cinnamon Bittern *I. cinnamomeus*,

and Great Egret *Egretta alba*.

The lakeside human population (approx. 80,000 in 1984; Marshall, 1984) makes extensive use of the lake's resources, particularly fish, crustaceans and molluscs, which are caught by a variety of traditional methods. There is thus the potential for considerable interaction between human and bird populations. In a previous paper (Pierce *et al.*, 1993) we examined the effect of fishing activity on the distribution and abundance of waterbirds in the lake. Most fishing activity is based on use of traditional "long-tailed" boats, with a crew of one or two, propelled either by use of a pole pushed into the lakebed or a small outboard motor. The fishermen make use of various kinds of traps and nets, as well as spear fishing (see Marshall, 1984; Pierce *et al.*, 1993). It was apparent that fishing could disturb waterbirds up to 150-200 m away, causing them to fly away from the immediate area. The amount of disturbance, as measured by the proportion of birds present that fled, depended on the type of fishing activity, eg groups of men beating the water's surface to herd fish into seine nets invariably led to all birds in the vicinity flying away whereas fishermen using hand-held push nets were largely ignored by birds. There were also differences between habitats (birds were generally more readily disturbed in more open habitats) and between species, eg 67% of egret groups on *Paspalum* grassmats flew away during experimental disturbance whereas only 18% of groups of Black-winged Stilts fled, and Stilts also allowed boats to approach closer before reacting (Pierce *et al.*, 1993).

In the present paper, we describe observations on bird movements in summer and autumn 1987, with particular regard to movements to and from roost

Table 1 Numbers of bitterns and egrets flying to and from the roost near Kukut. Total numbers moving north (N) and south (S) are given for each observation period. Most observations were Kukut but on 5 November 1987 observations were also made at a site to the north of the roost. Dusk was at approximately 1815 hrs.

Observation site	Date	Times	Bitterns		Egrets	
			N	S	N	S
Kukut	29.10.87	0715-1815	22	41	1671	0
Kukut	30.10.87	0615-0800	0	37	83	608
Kukut	02.11.87	1730-1815	403	0	1647	0
Kukut	03.11.87	0600-0800	0	283	2	923
Kukut	03.11.87	0615-1815	329	0	2064	0
Kukut	04.11.87	1700-1815	325	0	1793	0
Kukut	05.11.87	0530-0600	0	0	0	506
Kukut	05.11.87	1700-1815	368	0	1992	1
Roost	05.11.87	1730-1815	0	44	0	255

sites, and additional results on the distribution of foraging egrets, on grassmats in the lake, in relation to disturbance by human activities.

Such information on bird distribution and movements is important both to quantify the interactions between birds and man, and to provide baseline data against which to assess subsequent changes. Understanding of the overall movement pattern of resident birds is needed to allow conservation plans for the area to take full account of the needs of the species.

Methods

Study area

The climate is tropical with uniformly high temperatures, a light south-west monsoon in April to September and a heavy north-east monsoon in December to January. Further information on climate may be found in Evenson (1983), Marshall (1984) and Jintanugool & Round (1989).

The land on the eastern shoreline of the lake is largely cultivated, with paddy fields fringed by sugar palms. These are separated from the lake by a strip of mangrove or grassland. The paddy fields were dry with bare mud in June and July, but were flooded in October and November. A small island just north of the village of Kukut acted as a roost site for a large number of the egrets and bitterns studied. The roost site consisted of a number of trees, some reaching a height of 6 m, surrounded by short, dense vegetation. This appeared to provide a secure roost area.

Lake habitats in the vicinity of Kukut village include mats of floating grass (*Paspalum vaginatum*) and areas of sedges (*Scirpus litoralis*) and reeds (*Phragmites* spp.), all crossed by a network of channels used by fishing boats. Further out in the lake, there is open water, with submerged aquatic plants including *Najas* sp., *Ceratophyllum demersum*, *Hydrilla verticillata* and the green alga *Chara* sp., as well as several groups of islands (see Pierce *et al.*, 1993 for further description).

The grassmats (**Figure 1**) formed a band approx. 200 m wide and several kilometres long, parallel to the eastern shoreline of the lake. At Kukut, the mats began approx. 100-200 m offshore. The main vegetation in these mats was the grass *Paspalum vaginatum*, loosely rooted in the lakebed and with shoots rising 50-75 cm above water level.

Dial bird movements

Preliminary observations of dial movement patterns were made during June-July 1987 (summer period) alongside other studies (Pierce *et. al.*, 1991, 1993). Numbers of Lesser Tree Ducks (the most abundant species) flying past Kukut in the morning and evening were recorded. A more structured data collection procedure was adopted during a second visit in October-November 1987 (autumn period). No attempt was made to determine the breeding status of the birds being counted in either period. However, during studies of birds using the lake habitats in both summer and autumn (Pierce *et al.*, 1993) information on breeding was recorded. The only direct evidence of breeding was seen in June, when four nests and 21 broods of Moorhen and four nests and two broods of Little Grebe were observed (*pers.obs.*).

The pattern of bird movements was recorded using half-hourly counts of the

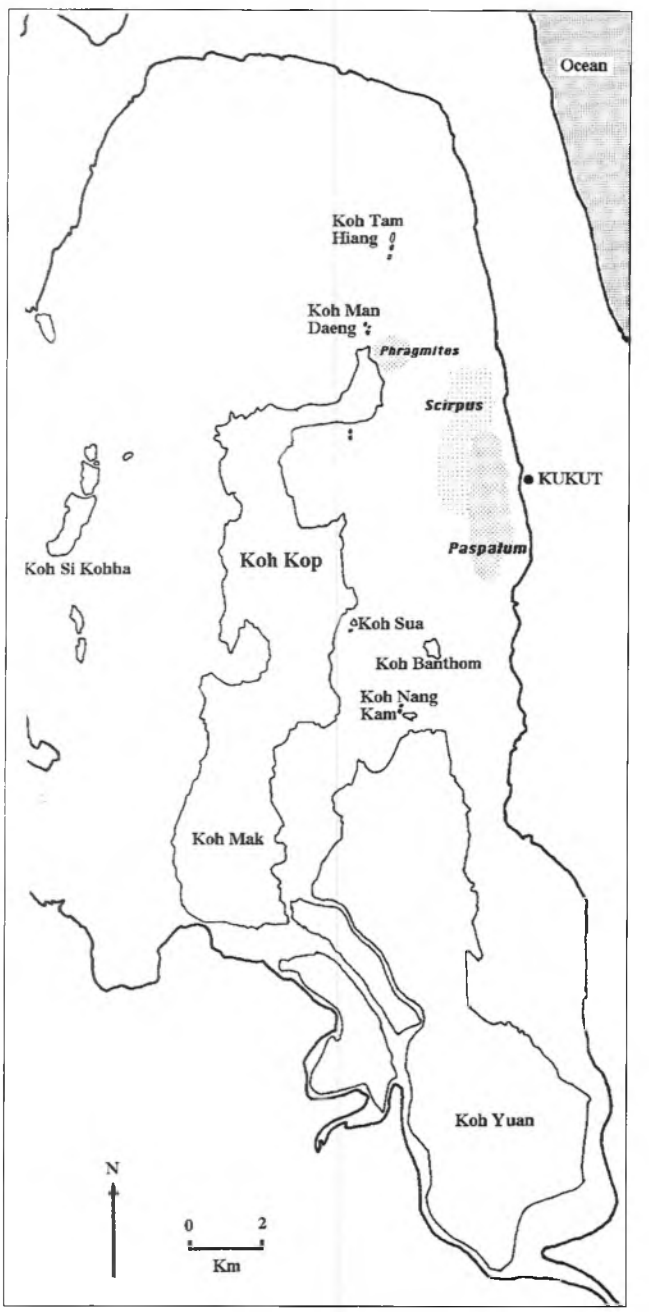


Figure 1.. Map of Lake Songkla. The part of the lake adjacent to Kukut is Thale Sap. Approximate locations of major habitat types are marked.

number of birds passing an observation site on the shoreline at Kukut village, on a line running east-west across the lake from Kukut. Counts were made during daylight hours (0600 - 1800) on 28-30 October and 2-6 November 1987, during which period each time of day was covered three to seven times (see **Appendix I**). For each count, numbers of birds flying north or south were recorded over a five minute period. During the main periods of movement by birds leaving and returning to the roost (0600-0800 and 1700-1815) groups of birds seen during intervals between the half-hourly counts were also recorded, allowing us to estimate the total numbers of bitterns and egrets travelling to and from the roost. During data collection, group sizes were noted for all species and for both directions.

Differences between species and effects of date, time of day, and direction of flight on numbers of birds recorded and group sizes were tested using Kruskal-Wallis tests. Both number and group size data were strongly skewed and could not be transformed to normal. Because the use of non-parametric tests precludes tests for interactions between factors and evaluation of confounding effects, ANOVA was also used. ANOVA results must however be regarded as provisional given the non-normality of the data. For analysis, only the most frequently seen categories (bitterns, ducks, egrets, terns) were included and observations were grouped into three date classes (28-30 Oct, 2-3 Nov, 4-6 Nov) and three time-of-day classes (before 0800 h, 0800 to 1600 h and after 1600 h). These groupings gave a reasonably even distribution of data between classes. Trends identified were tested using Spearman's rank correlation coefficient.

It became apparent during data collection that large numbers of bitterns and egrets used a roost site approx. 1 mile north of Kukut village. Movements to and from this roost were quantified by counts around dawn and dusk. In addition to counts from Kukut, numbers of birds moving to the roost at dusk from the north were counted on 5/11/87. These data were incorporated into estimates of average group size but excluded from other analyses of group size.

The distribution of egrets on grassmats

Egrets are perhaps the most readily observed birds on the lake, being clearly visible from a long distance. Egrets were often present on grassmats immediately west of Kukut village (**Figure 1**) throughout daylight hours, and large numbers landed on the more northerly mats immediately after leaving adjacent roosts in the morning, and before returning to the roosts in the evening. The mats appeared to be an important foraging site for egrets, with large numbers of birds feeding along the edges of the mat and in channels through the mats. The number of egrets present on the grassmats, and the incidence of disturbance by the presence of human fishing activity, were measured using half-hourly counts, contemporaneous with the counts of moving birds. For this purpose, the area of *Paspalum* was divided into seven mats (demarcated by large channels), numbered from south (1) to north (7). For each count, the number of egrets present on each mat was recorded and presence or absence of human disturbance at each mat noted.

Data were analysed using non-parametric statistics (Kruskal-Wallis tests and Spearman's rank correlations) to

evaluate the effects on numbers of date, time of day, location, presence of human activity at the same mat or other mats (either concurrently or at some time previously), and the number of egrets present previously. Although the egret data were strongly skewed and not transformable to normal, ANCOVA was used to allow possible interactions between factors and confounding effects to be evaluated. For the ANCOVA, disturbance was coded as present/absent and the other variables (number of birds present 30 minutes previously, time of day and mat position) were entered as covariates. Since there was no *a priori* hypothesis regarding the time-frame over which disturbance operated, the analysis was repeated to evaluate the effects of time-lagged disturbance, ie disturbance 0, 30, 60, 90 and 120 minutes prior to counts. When evaluating the effect of disturbance with a time-lag $t = L$ minutes, the appropriate covariate is number of birds present at $t = -(L+30)$ minutes.

Results

Dial bird movements

In the summer period, the morning passage of Lesser Tree Ducks, northwards past Kukut, began before 0600 h (when it was too dark to count), and had finished by 0730 h. The evening passage took place mainly between 1800 and 1900 h (after which it became to dark to count). In contrast to movements during the day, at this time the Lesser Tree Ducks were flying high and direct, southwards, in groups of up to 50 birds. On 2/7/87, a total of 4530 birds was counted between 1810 h and 1900 h, with a peak of 128 birds/minute over the ten minute period from 1831 h to 1840 h. No evening or morning passage up or down the lake was observed for Cotton Teal.

Species recorded in flight during the autumn period are listed in **Appendix II**.

Table 2. Overall average half-hourly counts and average group sizes for flying birds. Sample sizes (N), and mean and median values are given for the most important bird categories (for details of species within each category see Appendix II). Half-hourly counts include birds moving North and South.

	Half-hourly counts			Group Sizes		
Species	N	Mean	Median	N*	Mean	Median
Egrets	115	21.22	1	2039	6.76	2
Terns	115	14.57	6	710	2.38	1
Ducks	115	9.10	5	377	3.41	2
Bitterns	115	3.29	0	995	2.00	1
Cormorants	115	0.26	0	12	2.50	1
Moorhens	115	0.17	0	16	1.25	1
Swallows	115	0.06	0	25	2.89	2

* Numbers of groups moving north were respectively 1050, 345, 214, 635, 3, 9, 9 and numbers of groups moving south were 924, 365, 163, 327, 9, 7, 16. Numbers of Bittern and Egret groups counted north of the roost were 33 and 65 respectively.

Table 3. Summary of statistical analysis for numbers and group size. Kruskal-Wallis tests were used to identify differences in relation to direction of flight, time of day and date. Three-way ANOVA allows interactions between factors to be tested. Spearman's rank correlation coefficients were used to test for correlations with time of day. In all cases, probabilities are given in parentheses, significant values being indicated by bold type. Sample sizes are as in Table 2 (** indicates that not all interactions could be tested due to small sample sizes in some groups).

	Kruskal-Wallis test H Values			3-way ANOVA results	Correlations (Spearman's R)	
Species	Direction	Time of day	Date	Factors with significant effect ($P<0.05$)	North	South
(a) Numbers of birds recorded flying during half-hourly counts						
Bittern	3.0(0.084)	31.3**(<0.001)**	1.1(0.571)	Time of day, time-direction interaction	0.551**(<0.001)**	0.643**(<0.001)**
Duck	10.4**(0.001)**	1.6(0.453)	8.6**(0.014)**	None	-0.016(>0.05)	-0.224**(<0.05)**
Egret	7.6**(0.006)**	9.7**(0.008)**	0.4(0.829)	Date, time of day, all interaction terms	0.458**(<0.001)**	-0.685**(<0.001)**
Tern	0.4(0.548)	12.0**(0.002)**	12.2**(0.002)**	Time of day	-0.087(>0.05)	-0.189(>0.05)
(b) Group Sizes						
Bittern	24.6**(<0.001)**	35.1**(<0.001)**	14.6**(0.001)**	Time of day, direction**	0.189**(<0.01)**	-0.169**(<0.01)**
Duck	0.0(0.865)	11.1**(0.004)**	1.8(0.402)	None	0.171**(<0.05)**	0.084(>0.05)
Egret	37.2**(<0.001)**	116.0**(<0.001)**	29.0**(<0.001)**	Time of day, direction**	0.124**(<0.01)**	-0.274**(<0.01)**
Tern	2.1(0.147)	59.2(<0.001)	14.7(<0.001)	Time of day, direction, time-direction interaction	-0.252**(<0.01)**	-0.224**(<0.01)**

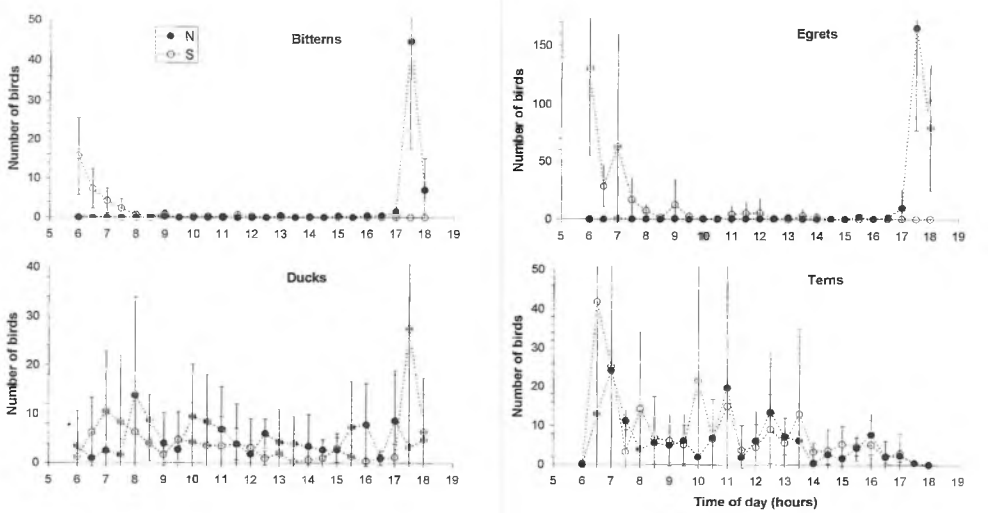


Figure 2. Average numbers of birds recorded flying northwards and southwards past Kukut during half-hourly counts at different times of day, autumn 1987: (a) Bitterns, (b) Ducks, (c) Egrets, (d) Terns. The error bars are 1 standard deviation.

The numbers of ducks recorded flying past Kukut were lower than in the summer: the maximum estimated daily total count of ducks (all species) moving in one direction was 1026 (171 birds were counted; counts occupied 5 minutes of each 30 minutes). The maximum estimated uni-directional daily total for terns was 2052. Repeat counts of the same birds moving North and South cannot however be ruled out.

Egrets and bitterns used the roost site north of Kukut. Numbers counted moving to and from the roost site appear in **Table 1**. Although counts were not coincident on all days, the results suggest that upwards of 400 bitterns and 2000 egrets moved between feeding sites to the south and west of Kukut to roost at this site. This agrees fairly closely with maximum uni-directional daily totals estimated from the regular half-hourly observations at Kukut (510 bitterns and 2292 egrets). Lower numbers of bitterns and egrets were recorded in the morning than in the evening, suggesting that some birds either left the roost before dawn or made more circuitous movements around the lake. Additionally, smaller numbers of egrets and bitterns were observed approaching the roost from the North on 5/11/87 (**Table 1**) and may make regular use of feeding sites in the north of the lake. Egrets leaving the roost in the morning tended to move initially to the nearest *Paspalum* mat before flying southward. In addition to Little Egrets and Great Egrets, Cattle Egrets and one Grey Heron were also seen at the roost.

Overall, similar numbers of birds were in flight each day throughout the observation period and numbers moving north and south were similar (but see below). This suggests that observations are largely of daily movements by resident birds. Overall average half-hourly counts for the most commonly seen categories of birds are seen in **Table 2**. The four most commonly seen categories of birds were bitterns,

ducks, egrets and terns. In contrast to the bitterns and egrets, which were seen flying primarily at dawn and dusk, ducks and terns were recorded flying past Kukut throughout the day (**Figure 2**).

Further statistical analysis (see **Table 3**) was restricted to these four most common bird categories. Median half-hourly counts differed significantly between bird categories (Kruskal-Wallis $H=84.5$, $P<0.001$) and they were therefore analysed separately. Counts were also split into north and south components. Significant variation in numbers in relation to time of day was seen for bitterns, egrets and terns. Differences in average counts between days were seen for ducks and terns. Average numbers of birds moving north and south differed for ducks and egrets, with more birds seen flying north. This could indicate some net movement through the study area.

The results from 3-way ANOVA (**Table 3**) supported some of the Kruskal-Wallis test results: differences related to time of day were found for bitterns, egrets and terns and differences between days were found for egrets. A significant interaction between effects of time of day and direction was seen for bitterns and egrets, consistent the predominantly southward movement from the roost site in the morning and northward movement to the roost site in the evening. Correlation results (**Table 3**) confirm these trends, as well as indicating that more ducks flew south later in the day than earlier. Finally, for egrets, interactions between all three effects (time of day, date and direction) were significant.

Group sizes

Average group sizes are indicated in **Table 2**. Overall, egrets tended to move in the larger groups than other species (**Table 2**). Group sizes differences between the four main bird categories were significant (Kruskal Wallis $H = 397.9$, $P<0.001$) and data for each were therefore analysed separately (see **Table 3**). In bitterns, ducks and egrets group size varied significantly in relation to time of day. This is consistent with the subjective impression that group sizes were largest for birds leaving roosts in the morning (flying south) and arriving at roosts in the evening (flying north). In bitterns and egrets average group size was bigger for birds flying north than for birds flying south. Although return to roosts appeared to be less synchronous than departure, group sizes of returning birds were thus slightly bigger. Kruskal-Wallis tests also suggested significant differences in group size from day to day but these differences were not supported by ANOVA results, possibly indicating that differences between days were simply an artefact of different sampling coverage of the different periods of the day (**Table 3**). Groups sizes were significantly larger earlier in the day for bitterns, egrets and ducks flying south and significantly larger later in the day for bitterns and egrets flying north, consistent with birds travelling in larger groups when moving to and from the roost. Tern groups moving north and south tended to be larger earlier in the day (**Table 3**).

Egret distribution on grassmats

Numbers of egrets differed significantly between mats, being higher on more northerly mats, and also varied significantly between days and in relation to time of day (see **Table 4**). More egrets were present on the grassmats in early morning and early evening. On the most northerly mat (7), numbers were highest in early morning, after which egrets tended to

Table 4. Results for statistical analysis of egret numbers on grassmats. Non-parametric statistical results are H values for Kruskal-Wallis (K-W) tests and R values for Spearman's rank correlation (RC). Local disturbance refers to disturbance events on the same grassmat, general disturbance refers to disturbance anywhere in the grassmat complex. Effects of disturbance with different time-lags (*L* minutes previously) are evaluated. Correlations between current numbers and those *L* minutes previously are also evaluated. Significant results are highlighted in bold type [*For this analysis, effects of covariates, as evaluated by student's *t* were: mat number t=5.45 (P<0.001), time of day t=-3.70 (P<0.001), number of egrets present prior to disturbance (ie 90 minutes prior to current time) t=3.68 (P<0.001)].

	Non-parametric tests			ANCOVA	
Factor	Test	Result	Probability	F value	Probability
Mat	K-W	325.2	**<0.001**		
Mat	RC	0.547	**<0.001**		
Date	K-W	18.9	**0.005**		
Time of Day	K-W	63.9	**<0.001**		
Local disturbance *L*=0	K-W	0.0	0.967	0.60	0.438
Local disturbance *L*=30	K-W	1.72	0.190	2.73	0.099
Local disturbance *L*=60	K-W	4.57	**0.032**	4.33	***0.038**
Local disturbance *L*=90	K-W	0.46	0.498	0.00	0.944
Local disturbance *L*=120	K-W	0.05	0.823	0.62	0.433
General disturbance *L*=0	K-W	0.0	0.967	0.19	0.664
General disturbance *L*=30	K-W	0.4	0.535	0.01	0.907
General disturbance *L*=60	K-W	0.9	0.335	0.07	0.792
General disturbance *L*=90	K-W	0.1	0.810	0.13	0.722
General Disturbance *L*=120	K-W	0.1	0.790	0.02	0.894
Number of egrets *L*=30	RC	0.677	**<0.01**		
Number of egrets *L*=60	RC	0.634	**<0.01**		
Number of egrets *L*=90	RC	0.584	**<0.01**		
Number of egrets *L*=120	RC	0.570	**<0.01**		
Number of egrets *L*=150	RC	0.555	**<0.01**		

move onto the other mats and elsewhere (**Figure 3**).

There was strong temporal autocorrelation in counts, ie numbers were positively correlated with numbers present 30-150 minutes previously (**Table 4**).

Kruskal-Wallis test results indicated that numbers of egrets were significantly lower on mats disturbed 60 minutes previously than on undisturbed mats. This effect of local disturbance is supported by ANCOVA results, although the effect was small relative to the differences between mats, between different times of day and the effect of the number of egrets present prior to disturbance (**Table 4**). Repeating the analyses for different time-lapses, effects of disturbance were non-significant. Thus disturbance earlier or later than 60 minutes previous to observation had no significant effect on egret numbers. Disturbance due to human activity on adjacent mats (ie general disturbance) had no discernible effect (**Table 4**).

Discussion

The results on movements reveal a clear pattern to use of the lake by resident birds, as well as providing some indication of the numbers of birds using the Thale Sap Non-Hunting Area during 1987.

Three species of duck were seen during the study, of which the Gadwall *Anas strepera* was seen only once, a small group being present in the grassmats on one occasion in November. Lesser Tree Ducks were the most abundant species of waterfowl in the summer and, on one occasion, over 4000 were recorded moving past Kukut. However, around 85% of the ducks observed in the lake (as opposed to in flight) during June were Cotton Teal. In autumn, the proportions of the two species seen in the lake shifted dramatically, with around 90% being Lesser Tree Ducks (see Pierce *et al.*, 1993). Thus, although the species of duck was not usually distinguished during the regular counts of birds in flight in the autumn, it is reasonable to assume that the majority were Lesser Tree Duck.

In the autumn, it became apparent that many birds, particularly bitterns and egrets, used a single roost site on an island to the north of Kukut village. Egrets were the most numerous bird category seen in flight, with some 2000 birds using the roost site, the majority of which appear to move past Kukut en route to their foraging areas. Egrets and bitterns tended to fly in larger groups than the other species, as might be expected since egrets and bitterns were most frequently seen during travel to and from the roost. Group sizes tended to be higher for birds returning to the roost than birds leaving the roost, apparently implying greater synchrony in returning birds, although the subjective impression during observations was that departure from roosts was more synchronous than return.

Bitterns and egrets were seen flying mostly at dawn and dusk, whereas ducks and terns were seen in flight throughout the day, but with higher numbers before noon. The statistical analysis confirms that the majority of bitterns and egrets seen in flight were moving from the roost to the lake and back, spending most of the day (0800 -1630) in the lake. Observations on habitat use by birds in the lake (Pierce *et al.*, 1993) suggest that bitterns in the lake were distributed fairly evenly between *Paspalum* grassmats and *Phragmites* reed beds, although Cinnamon Bittern dominated in the former and Yellow Bittern in the latter. Egrets were largely

confined to the grassmats.

While both bitterns and egrets foraged mainly in vegetated areas of the lake, terns foraged over open water and their mode of foraging presumably explains their continued flight activity throughout the day. In June, groups of Whiskered Tern *Chlidonias hybrida* were seen feeding and resting among old fish traps in areas of sparse *Scirpus* sedge. In November large numbers of terns were seen daily, feeding by plunge-diving near the edge of the lake. Groups were seen patrolling sections of the lake edge while feeding (*pers. obs.*). Little Terns *Sterna albifrons* were seen only in the autumn, in small numbers in mixed groups with Whiskered Terns. The Little Terns were probably on migration at this time.

Ducks make use of all the lake habitat-types, including *Scirpus* sedge beds as well as the habitats already mentioned. The daily movement of ducks around the lake was probably the result of their seeking suitable feeding in these areas as well as being due to their avoidance of predatory species.

Egrets clearly form an important part of the overall bird assemblage of the lake. Since they feed mainly on small fish and invertebrates it is obvious that their foraging sites may well be the same as those selected by human fishermen. Thus men and egrets may be expected to occur in close proximity on the edges of the *Paspalum* mats and in the channels dividing the mats. While observations analysed were collected over a limited time period they do show some interesting trends in the use of mats by egrets.

Firstly, it was clear that egrets used the mats to differing extents at different times of day, with the maximum numbers present on them just after roosting periods. In the evening, although no build up in numbers is apparent in **Figure 3**, egrets were seen to congregate on the *Paspalum* mats prior to moving back to the roost.

The degree of disturbance to birds on the mats was rather difficult to assess in the field, however it is felt that the methodology used in the present study does offer a standardised recording technique. The results indicate that disturbance due to human fishing had a significant depressive effect on the numbers of egrets using a particular mat. However, disturbance at adjacent mats had no discernible effect on egret numbers, suggesting that the effect of disturbance was localised. During the period of field observation, the *Paspalum* grass was very short, allowing good visibility to (and of) the pre-roosting and foraging birds. Any presence of fishing activity at this time of year is therefore likely to be detected by birds, although at other times, when vegetation is taller, some fishing activity may go undetected. Observations suggested that birds rarely flew away from disturbances that were more than 100 m away.

The number of birds present on any one mat was depressed if there had been disturbance there up to 60 minutes previously. There was also a strong relationship between the number of birds present at any one time and the number present at the same mat 30 minutes previously. It is important to note here that many bird species use a number of social cues when deciding where to roost, forage, or carry out various other activities. One of the prime determining factors in this evaluation has been shown to be the behaviour of conspecifics. Thus, in the present case, if a mat already holds egrets it is likely to become a more attractive place for other egrets to land. If, however, these birds have been scared off

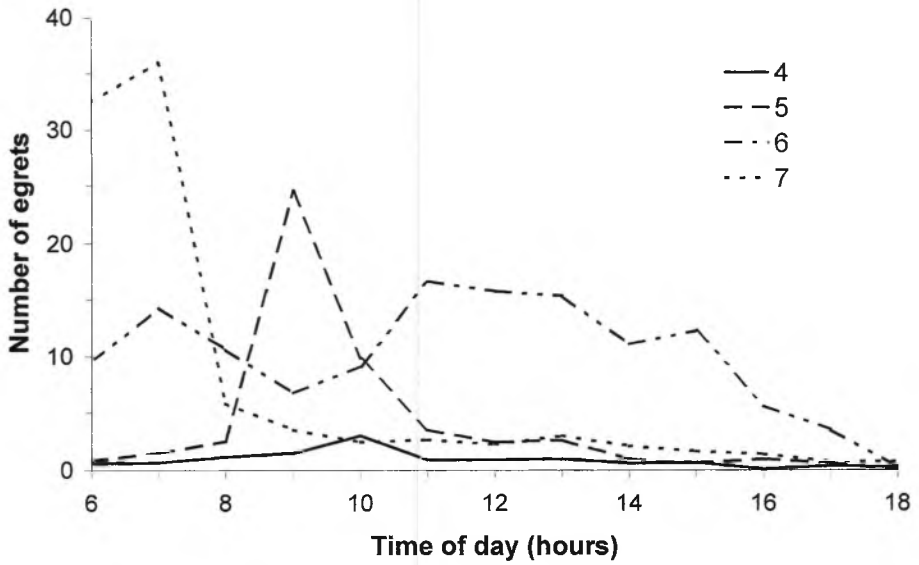


Figure 3. Average numbers of egrets seen during each observation, on mats 4-7 at different times of day. Mat 7 was the most northerly, closest to the roost.

by fishing activity (up to one hour previously), the mat thus becomes less attractive, and numbers will be consequently slow to build up again. This may well account for the depression in numbers up to one hour after disturbance, and the high correlation between numbers present and numbers of birds present 30 minutes previously.

Observations confirmed the importance to birds of a part of the reserve with a relatively high human population, notably the presence of a significant roost site very close to the village. Several studies have shown that the roost site of many bird species is particularly sensitive to disturbance. The disruption of roosts may have major implications for the viability of species in an area. Similarly pre-roosting areas, such as *Paspalum* grassmats in this case, have been shown to be of importance as social gathering areas free from high levels of disturbance found in other parts of a species' range. Adverse effects of human disturbance on breeding birds, particularly if it occurs in preferred feeding areas or at nesting sites, are well-documented (Tremblay & Ellison, 1979; Titus & Van Druff, 1981; Tuite *et al.*, 1984; Cooke, 1987; Mitchell *et al.*, 1988; Mueller & Glass, 1988; Keller, 1989).

This study, alongside the work described in Pierce *et al.* (1993) has demonstrated that human use of the lake can result in disturbance to waterfowl, as evidenced by localised, short-term depression in numbers of foraging egrets, and, in documenting aspects of habitat use by waterfowl in Lake Songkla, has identified some sensitive areas of the lake and lakeside habitat. Pollution of the lake's waters is also an issue and there have been studies on nutrients (Kanatharana & Chantanawatana, 1989), organic matter

(Sherdshoopongse *et al.* 1991), pesticides (Kanatharana *et al.* 1994) and trace metals (Sirinawin *et al.* 1998) in the lake.

Since late 1988, there has been development of aquaculture in the area, especially for shrimps, in Sathing Phra Peninsula. The presence of the shrimp farms has raised new issues with respect to conservation, including discharge water management, land-use conflicts and socio-economic problems. The lake continues to be an important fishery area and questions have been raised concerning interactions with a small population of Irrawady River Dolphin apparently present at the southern (saline) end of the lake (V. Lheknim, pers. comm.). There have been few ecological studies on the lake since 1988 when the "Kukut Project", a programme of ecological research initiated by Prince of Songkla University, finished.

Approximately 520 Km^2 of the lake is designated as Khu Khut Waterfowl Park, Asia's largest such park. However, the future of this park is by no means secure. Human use of the lake has increased and, indeed, tourist visits to the lake, where boats may be hired to explore the Waterfowl Park, are actively promoted. The most recent developments discussed in the local press include proposals for a tunnel under the lake and for a dam. The Songkla Lake Fisherman Assembly believes that the lake is becoming shallower due to siltation and water pollution is worsening due to household and industrial waste from Songkla, Hat Yai and Phatthalung (The Nation, 6 January 1997). A follow-up study of the human interactions with resident waterfowl would therefore be timely.

Acknowledgements

This work was carried out within the framework of the Kukut Project. Major sponsors of the study were the University of Aberdeen, the British Ecological Society, British Petroleum, Christian Salvesen Ltd, Clydesdale Bank, Dr Falqui, Gemoil, Grampian Regional Council, Italbroker, Tangram, and Thai Farmers Bank. We would also like to thank Augusto Vitale, Mike Harding, Eileen Stuart and Avril Conacher for assistance in the field and with organisation, Adrian Marshall for advice and encouragement, and Vachira Lheknim, Pimonpan Leelawathanagoon, Apichart Thammaruxs, Boongaue Withitham, Supareck Watanasit (Prince of Songkla University) and the Wana family (Kukut) for their hospitality and assistance. Cheryl Jones and Vachira Lheknim provided information on recent developments at Lake Songkhla and the paper benefitted from constructive comments from referees.

References

Anon., (1981). *Ecological Studies for Conservation of Shore Birds of Songkla Lake, Vol. 1*. National Environment Board, Bangkok. (NEB Pub. 1981-007).

Anon., (1982). *Ecological Studies for Conservation of Shore Birds of Songkla Lake, Vol. 2: Conservation Plan*. National Environment Board, Bangkok. (NEB Pub. 1982-002).

Cooke, A.S., (1987). Disturbance by anglers of birds at Grafham Water. In: *Angling and wildlife in fresh waters*, edited by P.S. Maitland & A.K. Turner, ITE Symposium no. 19, Institute of Terrestrial Ecology, pp. 15-23.

Evenson, J.P. (1983). Climate of the Songkhla basin. *Songklanakarin J. Sci. Technol.* **5**: 175-177.

Jintangugool, J. & Round, P.D., (1989). Thailand. In: *A Directory of Asian Wetlands*, edited by D. Scott, International Waterfowl Research Bureau, Slimbridge, pp. 667-736.

Kanatharana, P., Bunvunno, S. & Kaewnarong, B., (1994). Organochlorine pesticide residues in Songkla Lake. *Environmental Monitoring and Assessment* **33**: 43-52.

Kanatharana, P. & Chantanawatana, A., (1989). Study of nitrate and nitrite in Thale Sap Songkla - Water-Quality of Thale Sap Songkla-1. *Journal of Environmental Science and Health Part A-Environmental Science and Engineering & Toxic and Hazardous Substance Control* **24**: 87-96.

Keller, V., (1989). Variations in the response of Great Crested Grebes *Podiceps cristatus* to human disturbance - a sign of adaptation? *Biol. Cons.* **49**: 31-45.

King, B., Woodcock, M. & Dickinson, E.C., (1975). *Field guide to the birds of South-East Asia.*

Marshall, A.G. (Ed), (1984). The Kukut Project. *The Biological Resource Potential of the Kukut Area of Lake Songkla, Southern Thailand.* First Annual Report, 1983/4. Unpublished report to the Faculty of Science, Prince of Songkla University, Thailand, pp 123

Mitchell, J.R., Moser, M.E. & Kirby, J.S., (1988). Declines in midwinter-counts of waders roosting on the Dee Estuary. *Bird Study* **35**: 191-198.

Mueller, A.J. & Glass, P.O., (1988). Disturbance tolerance in a Texas waterbird colony. *Colonial Waterbirds* **11**: 119-122.

Pierce, G.J., Harding, M., Spray, C.J., Vitale, A., Stuart, E., Conacher, A., Readman, F., Galbraith, C.A. & Robinson, I.H., (1991). Otters of Lake Songkla, southern Thailand. *Journal of the Otter Trust* 1991: 25-32.

Pierce, G.J., Spray, C.J. & Stuart, E., (1993). The effect of fishing on the distribution of waterbirds in the Kukut area of Lake Songkla, southern Thailand. *Biological Conservation* **66**: 23-34.

Sherdshoopongse, P., Thapornsawati, S. & Kwankaew, J., (1991). The Distribution of Organic-Matter in Songkhla Lake Basin (Slb). *Environmental Monitoring and Assessment* **19**: 457-467.

Sirinawin, W., Turner, D.R., Westerlund, S. & Kanatharana, P., (1998). Trace metals study in the Outer Songkla Lake, Thale Sap Songkla, a southern Thai estuary. *Marine Chemistry* **62**: 175-183.

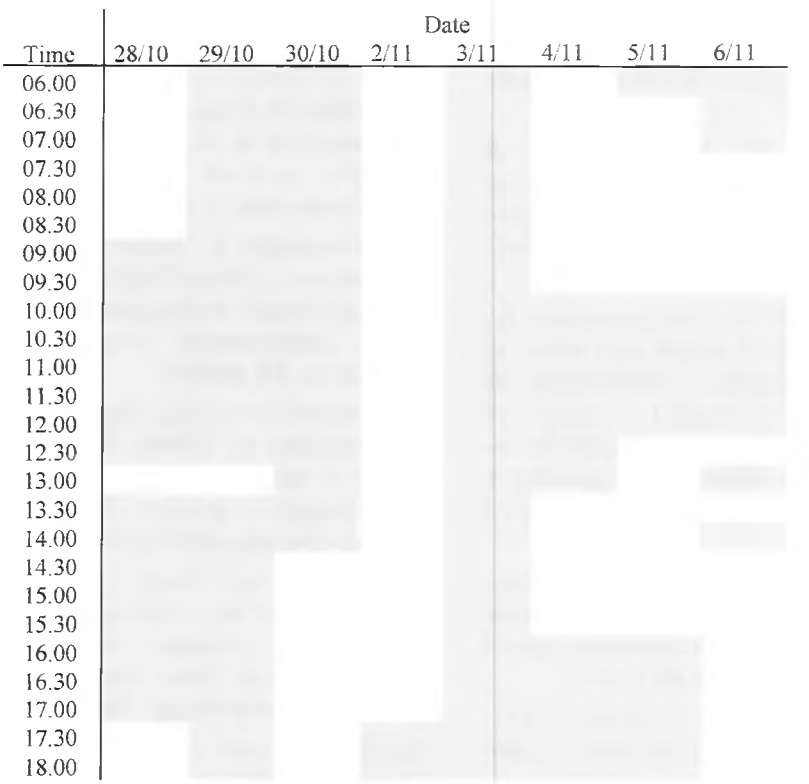
Titus, J.R. & Van Druff, L.W., (1981). Responses of the Common Loon to recreational pressure in Boundary Water Canoe Area, North-eastern Minnesota. *Wildl. Monogr.* **79**: 3-59.

Tremblay, J. & Ellison, L.N., (1979). Effects of human disturbance on breeding Black-crowned Night Herons. *Auk* **96**: 364-369.

Tuite, C.H., Hanson, P.R. & Owen, M., (1984). Some ecological factors affecting winter wildfowl distribution on inland waters in England and Wales, and the influence of water-based recreation. *J. Appl. Ecol.* **21**: 41-62.

Appendix 1

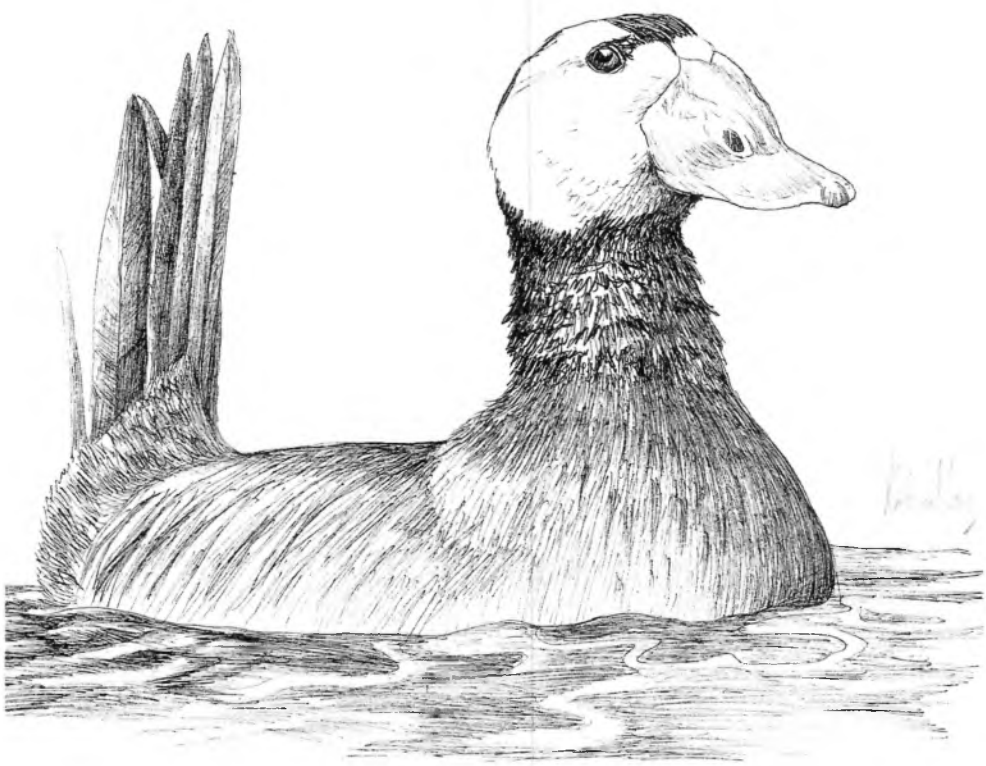
Observation periods for data on movements. Observation periods are indicated by solid rectangles.



Appendix 11

Bird species in flight recorded during observations at Kukut in the autumn of 1987. Common names are taken from King *et al.* (1975). Species within categories could frequently be distinguished, but were grouped together for analysis.

Category	Species Included
Bitterns	Yellow Bittern (*Ixobrychus sinensis*)
	Cinnamon Bittern (*Ixobrychus cinnamomeus*)
	Black Bittern (*Dupetor flavicollis*)
Cormorants	Great Cormorant (*Phalacrocorax carbo*)
	Little Cormorant (*Phalacrocorax niger*)
Ducks	Lesser Tree Duck (*Dendrocygna javanica*)
	Cotton Teal (*Nettapus coromandelianus*)
	Gadwall (*Anas strepera*)
Egrets	Little Egret (*Egretta garzetta*)
	Great Egret (*Egretta alba*)
Moorhen	Moorhen (*Gallinula chloropus*)
Swallows	Swallow (*Hirundo rustica*)
	Pacific Swallow (*Hirundo tehitica*)
	Edible-nest Swiftlet (*Collocalia fugiphaga*)
	House Martin (*Delichon urbica*)
	Sand Martin (*Riparia riparia*)
Terns	Whiskered Tern (*Chlidonias hybrida*)
	Little Tern (*Sterna albifrons*)
Others	Grey Heron (*Ardea cinerea*)
	Purple Gallinule (*Porphyrio porphyrio*)
	Common Sandpiper (*Acitis hypoleucos*)
	Oriental Pratincole (*Glareola maldivarum*)
	Black-winged Stilt (*Himantopus himantopus*)
	Red-wattled Lapwing (*Vanellus indicus*)
	Greenshank (*Tringa nebularia*)
	Common Kingfisher (*Alcedo atthis*)
	White-throated Kingfisher (*Halcyon smyrnensis*)
	Black-capped Kingfisher (*Halcyon pileata*)
	Black Drongo (*Dicurus macrocercus*)
	Crow-billed Drongo (*Dicurus annectans*)
	Northern Harrier (*Circus cyanus*)
	Brahminy Kite (*Haliastur indus*)
	Black-shouldered Kite (*Elanus caeruleus*)
	Sparrowhawk (*Accipiter nisus*)



White-headed Duck *Oxyura leucocephala*
drawn by Amanda Bradbury, WWT