Chapter 45

Time Series Analysis Course: 24–26 May 2005, Lüderitz, Namibia

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1. Background

The three-day course was presented by Prof. Les Underhill from the Avian Demography Unit, University of Cape Town, South Africa. The aim of the course was for each participant to bring a time series data set and during the course analyze the data and prepare the results for publication.

The course included lectures on different time series analysis techniques as well as on paper writing skills. The rest of the time was spent on data analysis, feedback sessions and group discussions. At the start of the course, participants introduced their data sets and described what they were hoping to achieve during the course. Because of the variety of data sets, participants were introduced to a multitude of problems and methods associated with time series analysis.

2. Summaries

Below are brief descriptions of each participant's dataset, objectives, methods used for analysis, as well as some preliminary results.

2.1. Rob Crawford, MCM, Cape Town

Responses of African Penguins and Swift Terns off western South Africa to a greatly increased abundance of food

Swift Terns *Sterna bergii* off South Africa eat mainly shoaling pelagic fish, especially Anchovy *Engraulis encrasicolus* and Sardine *Sardinops sagax* (Crawford and Dyer 1995), which have varied widely in abundance over the past two decades. Numbers of Swift Terns breeding at colonies in Western Cape Province have been counted annually since 1987. The breeding season is January to June (Crawford *et al*. 2002). From 1984–2004, the biomass of Anchovy and Sardine off South Africa in November has been estimated from acoustic surveys. From 1987–1993 and from 1987–2002, numbers of Swift Terns breeding closely followed the trend in the combined biomass of Anchovy and Sardine in the previous November. From 1993–1986 and 2002–2005, biomass of fish decreased but numbers of Swift Terns that bred increased. Large decreases in numbers of Swift Terns breeding from 1988–1991 and from 1986–1987 probably resulted from some birds not breeding when food became scarce. Stability in numbers breeding from 1993–1986 and 2002–2005, as fish abundance decreased, may have resulted from good recruitment to the breeding population as a result of good breeding in earlier years. Most Swift Terns initiate breeding when aged 3–6 years. The relationship between numbers of pairs breeding and biomass of fish suggests that as biomass increases above about 7 million tons, the numbers of terns that breed starts to level off.

2.2. Jessica Kemper, African Penguin Conservation Project, Lüderitz, Namibia

Breeding (a)synchrony of African Penguins at Halifax Island

In many colonial seabird species, including African penguins (*Spheniscus demersus*), counts of active nests at breeding peak are used to estimate the breeding population. This assumes that breeding is highly synchronized and therefore that all breeding pairs will breed simultaneously. We examined breeding synchrony between colonies at Halifax Island and investigated how consistent synchrony is over time. We evaluated whether peak active nests are a good index of the breeding population in a species with a prolonged breeding season, such as the African penguin.

Nests containing eggs or chicks have been counted in 27 areas on Halifax Island at monthly intervals since June 1995. Counts of active nests at the five largest discrete colonies were used in the analyses. For each colony, actual counts were interpolated linearly to give daily totals. For comparative purposes, counts were standardized to compensate for

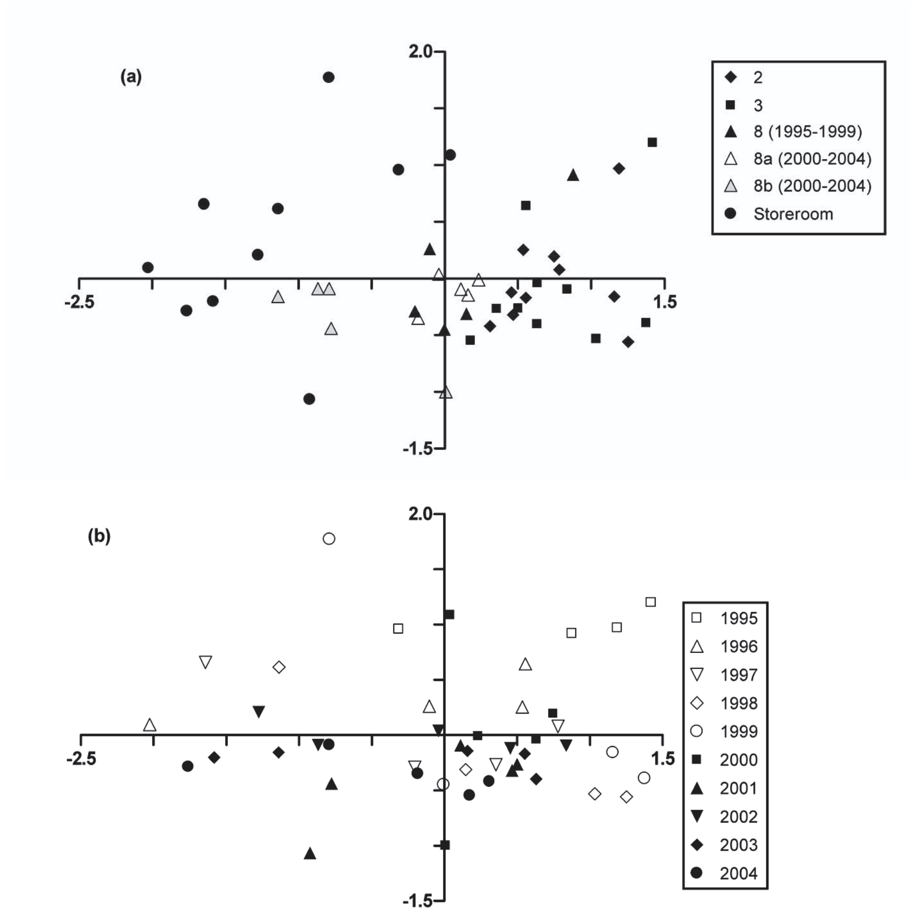

Figure 1: Plots showing grouping of (a) colonies and (b) years in terms of their timing of breeding

colony size differences. We applied multidimensional scaling, using the differences between daily totals to describe differences in breeding synchrony between colonies and between years. Multidimensional scaling plots observed similarities or dissimilarities ("distances") between colonies. A matrix of the annual sum of the absolute differences in scaled daily totals was constructed and distances between colonies and years were calculated using Genstat.

Between 1995 and 2004, penguins at Halifax Island bred throughout the year. Breeding activities were lowest during the primary adult moult peak in late April to early May, but never ceased. There were usually several breeding peaks per year and the timing of these peaks was erratic. Estimates of the breeding population using annual peak counts for the entire island were, on average, one third lower than those obtained by adding the peak annual count for each of the 27 areas.

Plots produced by multidimensional scaling (Figure 1) show points for two colonies (2 and 3) grouped close together. Pairs of points for these were plotted close together for any year. All points for the third colony (8a) were plotted close together but apart from colonies 2 and 3, while those for the fourth (8b) and fifth (Storeroom) colonies were more loosely spread and distant from the other colonies. Apart from points for 1995 and 2000, which were grouped well apart, points for other years were well mixed, suggesting that breeding synchrony patterns remained consistent between years.

Peak annual counts of active nests are a poor proxy for estimating the breeding population at Halifax Island, where breeding colonies are highly fragmented and breeding is not well synchronized between colonies.

The following paper is in preparation: Kemper, J., Roux, J-P. and Underhill, L.G. Breeding (a)synchrony of African Penguins at Halifax Island.

2.3. Steve Kirkman (MCM, Cape Town), Herman Oosthuizen (MCM, Cape Town), and Ndako Mukapuli MFMR, Lüderitz)

Trends in pup production of the Cape fur seal: the whole and its parts

Since 1971, censuses of Cape fur seals have been based on aerial photographic surveys of their pups in the breeding season. All available raw pup count data from 1971 to 2003 were presented at the workshop. The data comprise pup counts for each colony successfully surveyed, during each census. Analysis of the data set (for example to establish trends in pup production) is complicated by the many missing data points. These have resulted from exposure of film, inferior photographic quality, or omission of one or more colonies during a survey. Missing data have previously been estimated by linear interpolation, or by substitution using counts for the same colony in another survey. Such estimates are not always satisfactory.

At the workshop, an iterative algorithm for 'imputing' values of missing data was demonstrated. Colonies were first grouped together according to geography. Arbitrary values were inserted for missing data points, and the algorithm was then applied to the entire time series for each group of colonies, until convergence in the imputed values were obtained. An advantage of the method is that, in estimating a missing count for a colony, it takes into consideration the trends in pup numbers in surrounding colonies.

The following paper is in preparation: Kirkman S.P., Oosthuizen, W.H.O., Mukapuli, A.N. Roux, J-P., Underhill, L.G. and Meyer, M.A. Trends in pup production of the Cape fur seal: the whole and its parts.

2.4. Kumbi Kilongo, IMF Angola

Trends in catch and abundance of major groups of demersal fish off Angola, 1972–2004

For the Angolan data, information of demersal industrial catch from the Reports of the International Commission for the South-east Atlantic Fisheries (ICEAF) list catches of Benguela hake and large-eyed dentex from 1972 until 1984 (Crawford *et al.* 1987), and from “Direccao Nacional das Pescas” (DNP), of the Ministry of Fisheries of Angola from 1995 to 2004, the biomass estimated by Norway’s marine research vessel “Dr Fridtjof Nansen” from 1985 was used.

The objective was to collate information on the catch and abundance of the major categories of fish caught by bottom trawl off Angola (sparids, crockers, grunts, hakes, and groupers), since the inception of this fishery in the early 1970s. It is expected that this information will prove useful in the future management of the bottom-trawl fishery. Some of the information is used to provide a preliminary indication of the likely long-term annual yield of seabreams and groupers off Angola, using the production model.

The paper on “Trends in catch and abundance of major groups of demersal fish off Angola, 1972–2004” is in preparation.

2.5. Azwianewi Makhado, MCM, Cape Town

Impact of predation by Cape Fur Seals* Arctocephalus pusillus *on Cape Gannets* Morus capensis *at Malgas Island, Western Cape, South Africa

Growing fur seal populations are adversely impacting several seabird species that are of conservation concern. This is taking place through feeding on seabirds around breeding colonies, often inflicting heavy mortality that in some cases is thought to be unsustainable. Predation by Cape Fur Seals *Arctocephalus pusillus* on seabirds around Malgas Island in the West Coast National Park South Africa has been known for several years. Predation levels on Cape Gannets *Morus capensis* and cormorants *Phalacrocorax* spp. around Malgas Island were high in January and February 1999.

Observations of Cape Gannet mortalities resulting from predation by Cape Fur Seals were undertaken at Malgas Island during the austral summers of 1999/00 and 2003/04. Birds killed were recorded as either fledglings or birds in adult plumage.

In 1999/00, two observers monitored different areas during every alternate hour. Watches began at 06h00 and ended at 19h00. Therefore, on each day each observer conducted observations for seven hours. It was estimated that two-thirds of the area around the island was monitored. To estimate the number of birds killed each day, the number observed killed was doubled (to account for periods when no monitoring was done) and multiplied by 100/67 to account for that portion of the waters around the island that was not covered. This assumes that the predation rate was the same for hours not watched as for hours watched and for all areas around the island.

In 2003/04, one observer at the island kept watch from a vantage point, from which it was gauged that 67% of the waters around the island were covered. Observations were made each day from 06h00 until 18h00. Therefore, numbers of gannet chicks observed to be killed in the 12-hour period were increased by factors of 12/11 and 10/67. Data for 1999/00 and 2003/04 were pooled for intervals of one hour to investigate the period during which mortality occurred.

A total of 3 993 gannet chicks were observed to have been killed during the breeding 2003/4 season. Estimates of the total predation by seals on Cape Gannet fledglings over the period January–March 2004 were obtained by imputing values for days when no observations were made. Average daily predation rates were calculated for those weeks for which observations were made. For days when no observations were conducted, the average predation rates were estimated by interpolating linearly between the average values for the weeks immediately preceding and following the period with no information. Using this method, 10 226 chicks are estimated to have been killed during the whole period, which is half the estimated number of fledglings at the island (about 21 000).

The following paper is in preparation: Impact of predation by Cape Fur Seals *Arctocephalus pusillus* on Cape Gannets *Morus capensis* at Malgas Island, Western Cape, South Africa.

2.6. Kathie Peard, MFMR, Lüderitz

Wind and Sea Surface Temperature Time Series, Lüderitz

The Lüderitz upwelling cell is one of the key environmental features of the Northern Benguela – it is an area of active upwelling under a perennial southerly, upwelling favourable wind regime. Upwelled nutrients such as nitrate, phosphate and silicate are exported from the high wind stress, well mixed environment of the upwelling cell to more stable waters downstream. Consequently the biological productivity in the Northern Benguela is largely dependent on this upwelling.

The time series that were presented at the workshop were:

a) Dias Point Lighthouse wind speed and direction from 1960–2004. These observations from pressure plate and anemometer data had been decomposed into South–North (longshore) and West-East (on–offshore) vectors. The daily average for each was calculated from 3 readings per day taken at 08h00, 14h00 and 20h00.

b) Sea Surface Temperature (SST) from Luderitz based on one bucket temperature reading per day at 08h00 from 1973–2004.

Indices of upwelling based on southerly wind speed and on SST have been used to determine interannual and interdecadal variability of the upwelling cell. In order to calculate anomalies to compare current observations against the historical database one needs to first accurately calculate the "baseline" or long term average of the observations. This was addressed at the workshop. For each time series the average Southerly wind speed / temperature was determined per day across 44 (31) years from Jan 1 to Dec 31 (366 data points). The corresponding daily standard deviations of each daily average were computed. The Julian days 1–366 were converted to angles (theta) for each day. The sine / cosine of theta was calculated for each Julian day. Multiple regression was used to determine the best fit of the daily average / standard deviation by computing a sine curve by regressing the daily average / standard deviation (predictor) against corresponding days (sine/cosine theta). The adjusted r square value of the regression was noted. The first harmonic of the curve was computed by including sine /cosine 2theta, second harmonic included sine / cosine 3theta. The best fit to the data was decided by the adjusted r squares for each regression, which increased with each harmonic up to a point of stability. The harmonic with the maximum r square statistic and smallest Akaike's index was chosen. Although the Akaike's index continues decreasing, the visual fit of the curve did not improve past the second harmonic when the fitted curve was plotted against the daily average values.

"Best fit" curves were used to determine standardised anomalies of Southerly wind and SST, these can be used to determine periods of intense or weak upwelling within the time series and can be correlated with biological parameters (e.g. growth, biomass) of resource species in the Northern Benguela.

2.7. Jean-Paul Roux, MFMR, Lüderitz

Exploring the effect of environmental variability on the prey availability of the Cape fur seals: Myctophids and Goby in the diet of fur seals at Atlas Bay, Namibia

The Cape fur seal, *Arctocephalus pusillus*, is a predator of meso- and epi-pelagic organisms taken mostly over the continental shelf. The spatial and temporal variability in the fur seal's diet composition seems to reflect the relative abundance / availability of the different prey components. In southern Namibia, in the immediate vicinity of the Lüderitz upwelling cell, the fur seal diet was investigated by means of scat analysis since 1993/94 (132 scat samples to date). The main prey species in this area are juvenile Cape hake, *Merluccius capensis*, Pelagic Goby, *Sufflogobius bibarbatus*, and Myctophids, principally *Lampanyctodes hectoris*. The proportion of juvenile Cape hake in the fur seal diet was found to vary inter-annually in relation to the strength of the cohorts of hake pre-recruits; the availability of juvenile Cape hakes to the seals is therefore a function of recruitment success of this species. The Pelagic Goby is found over the shelf of central Namibia down to a depth of approximately 90 m. Its biomass has increased since the collapse of the sardine and it has become the main forage fish for many predators in the area. Myctophids and *L. hectoris* in particular are mesopelagic species, which undertake considerable vertical migrations. They prefer cold waters and are concentrated over the shelf edge.

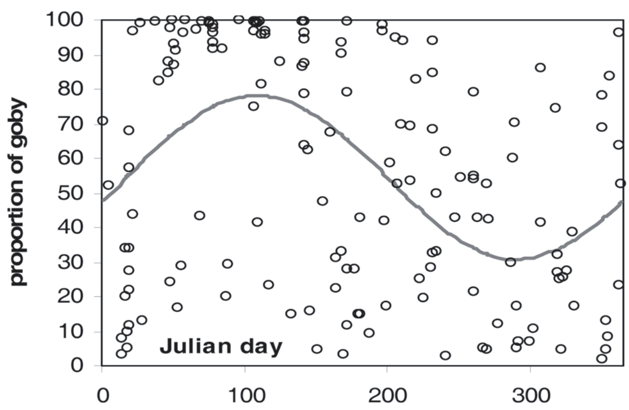

Figure 1: Illustration of the seasonal signal in the fur seal diet: the proportions of Goby in the Goby/Myctophid part of the diet in the scats samples collected since 1993 at Atlas Bay are plotted together with a simple Sine function (which explains more that 22% of the variability)

The fur seal colony of Atlas Bay is situated just to the south of the main Goby concentration and in an area of high perennial wind-induced upwelling, which brings inshore cold upwelled water from the shelf edge where Myctophids are abundant. The diet record shows a strong seasonality in the relative contribution of Myctophids and Goby to the fur seal diet with a maximum of Goby in the second half of April and a minimum in late October (Figure 1). This seasonal signal

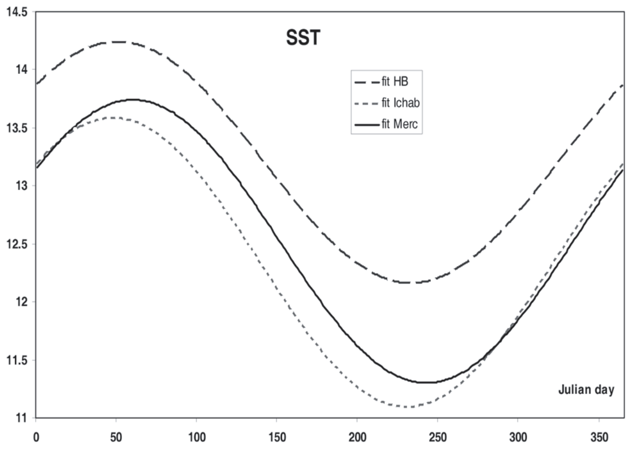

Figure 2: Average seasonal change in SST at Luderitz Harbour (HB), Ichaboe Island (Ichab) and Mercury Island (Merc) for the period 1993–2005

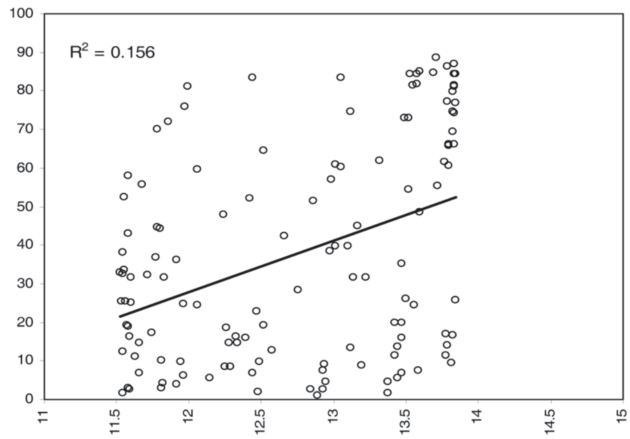

Figure 3: Arcsine of the proportion Goby/Myctophids in the diet plotted against the average SST cycle

suggests seasonal changes in the relative availability of these two preys that could be environmentally mediated. In order to investigate this possibility, time series of sea surface temperature (SST) are examined in relation to the diet data.

In a first step, the seasonal signal of the SST time series from Lüderitz Harbour, Ichaboe Island and Mercury Island (close to the center of Goby distribution) and the average between those three localities were modelled using simple Sine functions since June 1993 (2 863, 4 203, and 4 150 data points respectively). The fits corresponding to the average seasonal change in SST for those three localities are illustrated in Figure 2 and explain 28.3%, 47.2% and 39.9% of the variability respectively.

Simple cross correlations between the average SST cycle and the diet data show that SST explains about 15% of the variability of the ratios of Goby and Myctophids in the diet (Figure 3). Moreover, the SST anomalies (residuals) plotted in the same way also yield a positive significant relationship strengthening the hypothesis that the relative Goby/ Myctophid availability to the seals is under the influence of warm/cold SST.

The next step in this analysis was to attempt the more correct method of binomial correlation between the diet data and the SST data. Preliminary results confirm the above.

Future: The full analysis of the updated data sets needs to be performed using the methodology tried at the workshop paying particular attention to the phase differences (time lags) between the SST variability and the observed changes in the diet. A joint paper will be written emphasizing the dependence of the Goby/Myctophid part of the fur seal diet on environmental variability, seasonal cycles and anomalies which point to a bottom up effect on the predation rates. The prospective co-authors for this work are J-P. Roux, L.G Underhill, K.R Peard and S. Mecenero.

3. List of participants

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