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Attendance Patterns and Effects of Disturbance to Common
Murre (*Uria aalge*) Populations at Point Reyes National
Seashore, California, 1995-1997

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Abstract

We surveyed six Common Murre (*Uria aalge*) colonies in the vicinity of Elephant Seal Cove Beach (ESCB), Point Reyes National Seashore, Marin County, California from 1995 through 1997. This study was initiated to investigate the effects of disturbance to local murre populations in the wake of a small shipwreck and subsequent rescue operations on 10 June 1995. Following this Incident, the Cliff Rock West murre colony was abandoned, and three other murre colonies, Flattop Rock, Mid Rock, and East Rock, experienced reduced productivity due to subsequent disturbance and predation by Brown Pelicans (*Pelecanus occidentalis*), Western Gulls (*Larus occidentalis*), and Common Ravens (*Corvus corax*). Disruption and predation by these species continued in 1996 and 1997. Murres attended Cliff Rock West only early in 1996, and not at all in 1997. A new colony was formed at Northwest Rock after the abandonment of the Cliff Rock West colony in 1996. However, no eggs were observed at Northwest Rock in 1996 and the colony was abandoned early in 1997. Seasonal attendance of Common Murres on Flattop Rock, Mid Rock, and East Rock followed a similar trend in both 1996 and 1997. Murre attendance fluctuated widely until the onset of egg-laying in early May, and then remained stable until early July, when numbers increased significantly before a sharp drop at the end of fledging. Mean attendance increased 18-30% at these colonies between 1996 and 1997. Both air temperature and the upwelling index (UI) were significantly correlated with murre attendance in May and June during the incubation and nestling periods. Diurnal attendance in 1996 and 1997 varied both within and between colonies and days, yet there was a significant downward trend in attendance. Given that seasonal and diurnal attendance patterns of Flattop, East, and Mid Rocks in 1996 and 1997 appear similar, both between years and to other studies, we assume that these colonies are fairly stable. The 1995 cohort from ESCB colonies was reduced due to widespread low productivity in the year of the Incident. However, further conclusions as to the long-term effects of the Incident at ESCB are tenuous.

Introduction

Seasonal and diurnal attendance has been examined for a number of Common Murre populations (Lloyd 1975, Birkhead 1978a, Slater 1980, Gaston & Nettleship 1981, Harris et al. 1983, Hatch & Hatch 1989, Takekawa et al. 1990). During the incubation and nestling periods, attendance has been reduced extremely high winds (Birkhead 1978a, Gaston & Nettleship 1981), and warm, calm conditions (Murphy & Shauer 1994). Few studies have investigated attendance patterns in relation to disturbance. Aside from human disruption, disturbance to murre colonies may be related to potential predation, and recorded in the context of murre behavior, survivorship, productivity, and the costs and benefits of coloniality (Birkhead 1977b, Gaston & Nettleship 1981, Spear 1993, Sydeman 1993, Parrish 1995, Gaston & Elliot 1996, Schauer & Murphy 1996).

On 10 June 1995, the vessel Wayfarer, a 42' "Grand Banks" pleasure-craft, ran aground near Elephant Seal Cove Beach, Point Reyes Headlands, Marin County, California (Figure 1). As a result of the wreck, engine oil, debris, and approximately 200 gallons of diesel fuel were released into coastal waters. During the event, a U.S. Coast Guard helicopter was dispatched to the scene to rescue the one-man crew and later remove wreckage of the boat. In the wake of the grounding and subsequent rescue operations (hereafter referred to as "The Incident"), a monitoring program was initiated to investigate the effects of this disturbance to local Common Murre colonies.

We documented murre attendance patterns at these six coastal mid-California subcolonies beginning after this major human disturbance event and continued through 1997, including many episodes of smaller-scale disturbance caused by Western Gulls (*Larus occidentalis*), Common Ravens (*Corvus corax*), and Brown Pelicans (*Pelecanus occidentalis*). In the years following The Incident, we also examined differences in attendance between years, relationships between attendance and various atmospheric and oceanographic variables, and similarities with other colonies.

Methods

Elephant Seal Cove Beach (ESCB) is located in the center of the Point Reyes Headlands ($37^{\circ} 59.4' \text{ N}$, $123^{\circ} 00.3' \text{ W}$). Following The Incident in 1995, we monitored five Common Murre colonies in this area (Figure 1). Face Rock, East Rock, Mid Rock, and Flattop Rock are all near-shore sea-stacks where Common Murres breed in relatively small colonies. The Cliff Rock West colony occurs on a mainland cliff, and birds use ledges for breeding space. Our investigations began on 11 June, the day after The Incident, and continued almost daily until the end of June. After 30 June 1995, we surveyed each colony roughly twice/week through early August, at which time murres ceased to attend the colonies. Surveys in 1996 and 1997 were conducted from mid April to mid August, approximately twice weekly. In addition to the five murre colonies observed in 1995, a sixth colony, Northwest Rock, was added when murres were observed there early in the 1996 season. We logged approximately 137 hours of observation over 70 days during the 1996 and 1997 breeding seasons.

All surveys were made from a single observation point, located at the edge of an adjacent cliff (~400' elev.), using binoculars (8x42) and a Questar telescope equipped with a 32 mm eyepiece (60x magnification). We attempted to conduct bi-weekly surveys between 1000 and 1400 hrs in order to minimize confounding effects by diurnal variation in murre attendance (cf. Birkhead & Nettleship 1980). In practice, however, some surveys were postponed due to fog or heat waves. We counted the number of adult murres attending each colony three times in succession, as well as the number of potential predators in within 3 m of each colony and other disturbance events. For analysis, we averaged the three counts to obtain a single mean count for each colony for each day. To investigate overall seasonal attendance patterns, counts from the three largest colonies, Flattop Rock, Mid Rock, and East Rock, were used since they were the only colonies to breed in both 1996 and 1997. Atmospheric variables for the multiple regression analysis of seasonal attendance were obtained from Southeast Farallon Island (SEFI) databases ($37^{\circ} 41.8' \text{ N}$, $122^{\circ} 59.9' \text{ W}$), and values used were between 1000 and 1300 hrs. Sea surface temperature (SST) values were also measured at SEFI (C.L. Fey/ Scripps Institute of Oceanography). Upwelling index values were derived from barometric pressure measurements on the California coast at 39° latitude (Pacific Fisheries Environmental Group/ NOAA).

Pressure fields can extend over a substantial area, so as our study area was nearest 39° latitude, we used these UI values.

To assess diurnal attendance patterns, on five days each in 1996 and 1997, we also counted the three largest colonies (Flattop Rock, Mid Rock and East Rock) every 15 minutes, from 0700-1900 hrs. Dates were chosen to sample between mid egg-laying and first fledging -- roughly 15 May - 1 July, based, in part, on egg-laying and fledging data from the Southeast Farallon Island (SEFI) Common Murre populations (Boekelheide et al. 1990, Takekawa et al. 1990, Sydeman & Eddy 1995, PRBO unpublished data). This timing also was selected to minimize confounding by seasonal variation in attendance (cf. Hatch & Hatch 1989). Because poor weather conditions obscured observations on some days, we include data from only three all-day surveys in each year. We calculated moving averages ($n=7$ points) to investigate patterns of diurnal attendance (cf. Birkhead 1978a), so values are presented as the average of seven counts within each successive 1.5 hr period.

Attempts were made to establish study plots on each of the three largest colonies, Flattop Rock, Mid Rock, and East Rock. Unfortunately, site distinction was difficult due to the distance of our observation point and colony density. Steep cliffs coupled with increased probability of disturbance prohibited observation from vantage points nearer the colonies. We made only general estimates of productivity, based on colony abandonment or the observed numbers of eggs and chicks lost during disturbances.

Data analyses were performed using the STATA v. 5.0 statistical software package (Stata Corporation 1997). Significance was assumed when $P < 0.05$.

Results

The Incident 1995

In 1995, Common Murre colonies at ESCB were affected to varying degrees by the grounding and subsequent rescue of the Wayfarer. The Incident appeared to have a destabilizing effect on murres nesting on Flattop Rock, Mid Rock, and East Rock (Figure 2). Because these colonies were first censused on 16 June, we cannot address the immediate effects of The Incident

in great detail. Nonetheless, twelve destroyed eggs were observed on Flattop Rock on 11 June, and murres abandoned all colonies for unknown reasons during several subsequent censuses. Productivity at these colonies seemed to be reduced to very low levels in 1995, as we documented substantial loss of eggs and chicks to Brown Pelicans, Common Ravens, and Western Gulls.

The Cliff Rock West murre colony, closest to the site of the grounding, also appeared to be adversely affected by the Incident (Figure 2). Observations prior to the Incident in 1995 lead us to believe that there were approximately 150 murres at Cliff Rock West. After the Incident, the colony was attended sporadically from 11-20 June, but was then abandoned for the remainder of the season.

The Incident appeared to have little or no effect on murres at Face Rock (Figure 2). Face Rock was the farthest colony from the site of The Incident and murres attended this colony throughout the season with no observed abandonment or effect. Murres appeared to breed on Face Rock successfully, though we were unable to obtain productivity estimates.

Seasonal Attendance 1996-1997

Three colonies, Face Rock, Cliff Rock West, and Northwest Rock, were attended erratically. In April and May 1996, approximately 140 murres returned to Cliff Rock West (Figure 2). However, the colony was again abandoned, for unknown reasons, during a period of thick fog and heavy rain that precluded observations between 13-20 May. Cliff Rock West was not attended at all in 1997 ($n=31$ observation days). Although Face Rock exhibited initially high murre attendance in 1996, attendance dwindled in late May, and the west side of Face Rock was not used by murres for breeding either in 1996 or 1997.

Northwest Rock was added in 1996 as an additional study colony when twelve murres were seen roosting there on our first survey on 17 April (Figure 2). The colony was vacant, however, on the following ten observations. On 20 May 1996, the same day we recorded the abandonment of the Cliff Rock West colony, several murres were again observed on Northwest Rock. It is likely that some of the birds in attendance at Northwest Rock came from the abandoned Cliff Rock West colony. Small increases in attendance on 20 May were also seen at Mid Rock, East Rock, and Face Rock. Northwest Rock was then attended regularly throughout

the 1996 season, but no eggs or chicks were observed in this small colony. Murres returned to Northwest Rock in 1997. Colony attendance fluctuated early in the season and then the colony was abandoned by 30 May, perhaps related to Common Raven disturbance (see below).

Seasonal attendance patterns for the three largest ESCB colonies, Flattop Rock, Mid Rock, and East Rock, were similar between years (Figure 2). Attendance generally fluctuated during the first two weeks of observation at the end of April, followed by a period of relative stability. The beginning of the stable period coincided roughly with the onset of egg-laying in early May. Attendance began to decline in mid July and dropped sharply until all colonies were vacant by early August. Variation in this pattern was observed in 1996 when attendance increased substantially at all three colonies in early July, corresponding with an increase in numbers of birds seen wandering around the periphery of each colony. No such influx of murres was observed in 1997.

Linear regression analysis of attendance in May and June indicated a significant 33% increase in 1996 ($\beta=4.055 \pm 1.223$, $R^2=0.354$, $t=3.315$, $P<0.003$, $df=21$) and a slight 10% increase in 1997 ($\beta=1.813 \pm 0.890$, $R^2=0.257$, $t=2.038$, $P<0.064$, $df=13$) (Figure 3). Although the increase was not significant in 1997, this was perhaps due to a small sample size. Counts made during 1996 were not serially dependent (Durbin-Watson, $d=1.755$, $P>0.05$), however numbers in 1997 fluctuated less than in the previous year, and produced inconclusive results in the test for serial dependence (Durbin-Watson, $d_L < d = 1.084 < d_U$).

We determined that there were significant increases in the mean number of murres present at each breeding colony between years. As it is necessary to utilize a stable period in attendance for calculating annual differences in murre numbers (Birkhead & Nettleship 1980, Gaston & Nettleship 1981, Hatch & Hatch 1989), attendance in May and June was again utilized.

From 1996 to 1997, mean attendance at East Rock increased 30% from 75 to 103 birds, Mid Rock increased 18% from 271 to 332 birds, and Flattop Rock increased 27% from 413 to 569 birds (anova, $F=66.62$, $P>0.00001$, $df=107$).

Effects of Environmental Conditions

We examined the effects of various oceanographic and atmospheric variables (wind speed, air temperature, sea surface temperature, the upwelling index (UI), and all possible two-way interactions) on seasonal attendance patterns at each breeding plot in an analysis of covariance and multiple linear regression for May and June in 1996 and 1997. The final model fit the data quite well, producing an R^2 value of 0.9611 (Table 1). This model revealed significant relationships of both the UI and air temperature to murre attendance ($\beta = -0.153 \pm 0.038$, $t = -4.074$, $P = 0.0001$; $\beta = -5.827 \pm 2.254$, $t = -2.585$, $P = 0.011$, respectively, $df = 107$). Significant interactions between the year and date variables, the year and plot variables, and the plot and date variables were included in this multivariate analysis ($F = 4.94$, $P > 0.0285$; $F = 27.87$, $P > 0.00001$; $F = 4.91$, $P > 0.0093$, respectively). Air temperature was, however, a more subtle influence on attendance than the UI, and without the UI accounting for a large amount of variability, was not related to murre attendance ($\beta = -9.111 \pm 8.209$, $t = -1.110$, $P = 0.276$, $df = 107$). As upwelling is a process resulting from strong northwesterly winds, we expected windspeed to contribute significantly to the attendance model, but found no correlation using either exact windspeed measurements, average windspeeds, or lag windspeeds spanning 1-4 days prior to attendance counts. However, omitting all other oceanic and atmospheric variables, windspeed and windspeed³, which is the measure of ocean turbulence, each became significantly correlated to attendance in separate regression analyses ($\beta = -1.270 \pm 0.627$, $t = -2.026$, $P = 0.045$, $\beta = -0.0010 \pm 0.0005$, $t = -1.960$, $P = 0.053$, respectively, $df = 107$) (Table 2).

Diurnal Attendance

Patterns of diurnal attendance at Flattop Rock, Mid Rock, and East Rock varied both between and within colonies and days. Combining surveys from these colonies and displaying attendance as a moving average helped smooth out variance to present a clearer pattern (Figure 5). Surveys on 16 and 23 June 1996 were limited by fog, so comparison between the earliest and latest portions of the counts is somewhat problematic. Nonetheless, murre numbers were generally highest in the early morning around 0700 hrs, and declined through the late morning/early afternoon. Multiple regression analysis for all survey days indicated a significant

downward trend throughout each day ($\beta = -311.012 \pm 20.910$, $R^2 = 0.838$, $t = -14.874$, $P < 0.0001$, $df = 258$).

Figure 6 presents coefficients of variation calculated for the running means of diurnal attendance, indicating substantial variation in colony small-scale attendance patterns. Some variation can be attributed to occasional heat waves making mid-day counts difficult. However, we also documented a number of disturbances to murres, and many high CVs appeared to correspond to disturbance events. On the two days with minimal disturbance, 23 June 1996 and 20 June 1997, CVs were consistently low, characterizing stability. The period from approximately 1030-1300 hrs appeared to be most stable on both of these days, supporting the current practice of conducting whole-colony aerial photographic surveys of murre colonies in California, Oregon, and Washington, between 1000 and 1400 hrs (Carter et al. 1992, Sydeman et al. 1997, Manuwal et al. in prep.). Unfortunately, two days do not constitute a large sample with which to make definitive conclusions about the prime window for conducting surveys. Frequent disturbances to murre colonies warrant appropriate consideration by survey personnel.

Predation and Disturbance

Disturbance appeared to play a major role in ESCB Common Murre attendance patterns and productivity. In months following the 1995 Incident, disruptions by other bird species were common, and although no additional human disturbance events were recorded in 1996 and 1997, one pinniped disturbance was observed and disruptions by other bird species continued.

A seemingly ill, young Steller sea lion (*Eumetopias jubatus*) caused a disturbance to murres on 9 June 1996 at Flattop Rock. The pinniped's movements flushed murres throughout the day, and Western Gulls were quick to scavenge unprotected murre eggs.

We noted Red-tailed Hawks (*Buteo jamaicensis*) above ESCB numerous times during our study, but hawk predation on murres was not documented, and we never witnessed any interaction between hawks and murres.

We did, however, observe numerous disturbances by Brown Pelicans, often accompanied by opportunistic Western Gull predation. Brown Pelican disturbances were witnessed mainly in June and July, and typically involved a single, immature bird landing in or near a colony and

repeatedly scattering and/or flushing up to several hundred murres. Over the course of our study, immature pelicans were observed to eat numerous fish dropped by murres, five murre eggs, and on three occasions to pick up murre chicks, although we did not witness actual ingestion of any chicks. Additionally, pelicans caused at least 10 eggs to be crushed and more than 19 eggs to roll from their sites as a result of mayhem in the murre colonies.

Throughout the 1996 and 1997 seasons, pelicans were occasionally sighted flying in small groups but not causing any disturbance. Moreover, the appearance of relatively large numbers of Brown Pelicans in mid-July (groups of up to 45 birds) did not necessarily disrupt murres, even though they were occasionally roosting on the same sea-stacks as the murre colonies.

Common Ravens were both opportunistic and direct predators. In 1995, ravens took advantage of Brown Pelican disturbances to scavenge at least three murre eggs and one chick. Ravens initiated disturbances in all years, targeting peripheral murres. Attacks were seen only early in the 1996 and 1997 seasons (April and May), during which the ravens successfully preyed on at least one chick and two eggs.

In 1997, a possible raven nest was sighted on 16 May on Northwest Rock. This observation corresponded to a steep decline in murre attendance at the Northwest Rock colony, during a time when attendance at other colonies was becoming less variable. The possible raven nest looked abandoned, as it was seen on successive counts without any record of nearby activity. However, ravens were sighted on three subsequent days near other ESCB colonies. By 27 May, attendance on Northwest Rock had plummeted from approximately 50 murres down to four, two of which were in incubating posture, and one egg was sighted. On 30 May, the Northwest Rock murre colony was abandoned.

We did not witness any direct predation by Western Gulls. Western Gulls attempted to forage in murre colonies on a few occasions, but all observed predation occurred after murres were flushed off their eggs and/or chicks by other disturbances. We saw gulls take at least nine murre eggs and three chicks in the months following The Incident in 1995, and a total of 17 eggs and two chicks in 1996 and 1997.

The level of disturbance observed seemed high, and there were undoubtedly disturbances not witnessed. We were unable to calculate percent predation since total numbers of eggs and/or

chicks were unknown, yet the number of eggs and chicks lost during disturbances also seemed high.

Discussion

Seasonal Attendance

Common Murre seasonal attendance patterns observed at Flattop Rock, Mid Rock, and East Rock, were similar to those at the established Schubrick Point colony on the Southeast Farallon Islands (SEFI) in 1996 (Hester & Sydeman 1997) as well as patterns reported in a number of other studies (Lloyd 1975, Birkhead 1978a, Slater 1980, Hatch & Hatch 1989). In addition to highly variable attendance prior to egg laying and relatively stable attendance during incubation and nestling periods, other studies (e.g. Lloyd 1975, Slater 1980, Gaston & Nettleship 1981, Harris et al. 1983) found an upward trend in attendance through the incubation and nestling periods. SEFI murre attendance also increased during this period, by approximately 55% in 1996 and approximately 45% in 1997 (Hester & Sydeman 1997, Hester et al. 1998). The percent increase among studies ranged overall from 27% to 91%, compared to a 33% increase in 1996 and 10% increase in 1997 for May and June of our study.

Within this upward attendance trend, Gaston and Nettleship (1981) observed minor peaks in attendance which appeared to coincide with increased numbers of assumed non-breeders. We observed an attendance peak towards the end of the nestling period in July 1996, coinciding with more birds wandering near the periphery of each colony. Several investigators have suggested that immature murres may visit breeding areas late in the season to prospect for future breeding sites (Birkhead & Hudson 1977, Birkhead 1978b, Gaston & Nettleship 1981, Harris et al. 1983, Piatt & McLagan 1987, Halley et al. 1995).

There was no obvious influx of murres at ESCB in July 1997, as was seen in 1996. Trends at SEFI were just the opposite, with a slight influx in July 1997, but no such influx in July 1996 (Hester & Sydeman 1997, Hester et al. 1998). Murres at other Point Reyes Headlands colonies exhibited a July influx both in 1996 and 1997, although the increase in 1997 was somewhat smaller (USFWS/M. Parker, pers. comm.). Gaston and Nettleship (1982) suggested for Thick-billed Murres that attendance is ultimately determined by the size of the non-breeding

population and the availability of local food resources: if food is abundant, then non-breeders attend the colony in high numbers. In 1997, the upwelling index was generally high, perhaps indicating increased ocean productivity. Moreover, murre productivity on SEFI was higher in 1997 than in 1996, indicating availability of local food resources (Hastings et al. 1997). This appears to contradict our data which show no influx of murres in July 1997 at ESCB. One possible explanation is that there were not enough non-breeders in 1997 to register an attendance increase. Murres start returning to breeding colonies at two years of age (Birkhead & Hudson 1977, Halley et al. 1995). Therefore, 1997 would have seen the return of the 1995 cohort, which may have been reduced following the Incident. Another possibility involves earlier timing of breeding in 1997. SEFI murres bred approximately one week earlier in 1997 than in 1996. If the same were true at the ESCB colonies, then earlier departure of breeders in 1997 may have coincided with the typical influx of non-breeders in mid-July, resulting in a stable attendance pattern. However, in early July 1997, attendance at ESCB was actually decreasing, suggesting that an earlier departure of breeders coincided with the influx of a reduced non-breeder population due to the small 1995 cohort, resulting in overall decreasing attendance with a barely discernable influx.

This hypothesis seems to support other differences seen between 1996 and 1997 as well. A small 1995 cohort and non-breeder population may explain why there was only a low 10% increase in attendance in 1997, compared with a 33% increase in 1996. The more stable attendance pattern throughout the 1997 breeding season may also indicate fewer available non-breeders in the population, as non-breeders may cause many of the observed fluctuations in attendance patterns (Gaston & Nettleship 1982, Harris et al. 1983).

Influence of Oceanographic and Atmospheric Variables

Researchers have attempted to uncover connections between murre attendance and atmospheric and oceanic variables. When limited to the incubation and nestling periods, low attendance has been significantly associated with extreme weather conditions, such as high winds or heavy rain (Birkhead 1978a, Gaston & Nettleship 1981). We found both the UI and air temperature to be negatively correlated with murre attendance.

Of the oceanic variables analyzed, the upwelling index (UI) was very significantly correlated with attendance. The UI is an estimate of long-shore water movement ($\text{m}^3/\text{sec}/100\text{m}$ coastline) derived from barometric pressure measurements at coastal weather stations. The negative correlation between the UI and murre attendance patterns at ESCB may be partially explained by time spent searching for food, at the expense of time spent sitting at the colony (Monaghan et al. 1994, Uttley et al. 1994). Strong northwest winds which cause upwelling also produce ocean turbulence, which may limit resource-gathering conditions (Birkhead 1976). The UI is a complex variable, involving barometric pressure, wind stress, and ocean conditions. Thus it is not surprising that the UI accounts for more variability than simply other atmospheric variables alone.

The more statistically subtle effect of air temperature on murre attendance shows up only with the UI in the model. However, the effect of air temperature was biologically obvious on extremely hot days when we observed murres panting and standing upright off their eggs. Colonies were noticeably less dense on these days, indicating that non-breeders and off-duty mates most likely took refuge on the water. Similarly, Murphy and Schauer (1994) analyzed attendance with wind-chill equivalent temperature, revealing that on warm, calm days only breeders actively tending eggs or chicks remained on the colony.

Windspeed was not significantly correlated with murre attendance in the final model including the UI and air temperature. Only when the other atmospheric and oceanographic variables were omitted from the model did windspeed or windspeed³ produce significant results. This may be reasoned due to the association between the UI and windspeed. The UI is a complex variable involving elements of windspeed and as such seems to preclude significance of windspeed in the attendance model. The negative correlation of murre attendance with windspeed³, which is a measure of ocean turbulence, actually supports our above hypothesis that the negative correlation of attendance with the UI may be explained by difficult food-gathering conditions in a turbulent ocean surface layer.

Diurnal Attendance

Diurnal attendance patterns of murres vary widely. Birkhead (1978a) showed that diurnal attendance patterns differed according to the stage of the breeding cycle. Since seasonal

attendance is generally most stable during the incubation and nestling periods, this is when diurnal attendance patterns should be evaluated so as not to be confounded by trends of seasonal attendance. Our data resembled diurnal attendance of murres on Southeast Farallon Island (SEFI) on similar dates in 1996 (Hester & Sydeman 1997). Likewise, many other studies also exhibited an early morning increase in attendance, peaking around 0700-0800 hrs, followed by decline either immediately or later in the afternoon (Lloyd 1975, Birkhead 1978a, Gaston & Nettleship 1981, Harris et al. 1983, Hatch & Hatch 1989, Takekawa et al. 1990). Our data do not extend past 1900 hrs, so we cannot compare evening peaks reported by others (e.g. Slater 1980, Gaston & Nettleship 1981, Hatch & Hatch 1989).

Avian Disturbance

Brown Pelican disturbance at ESCB involved a lone, immature bird. Several late-season disturbances at ESCB in 1995 were caused by the same immature pelican, easily identified by a streak of oil on its breast. Deliberate colony disruption and consumption of other species' chicks by immature Brown Pelicans has been documented twice, both in a mixed-species heronry in Baja, California (Mora 1989) and at another Common Murre colony in the Point Reyes Headlands (PRNS/ A. Quintero pers. comm.). In 1986, Quintero observed several juvenile pelicans land repeatedly in a murre colony below the Point Reyes Lighthouse over a series of days and ingest a number of chicks. Such disruptive activity was similar to the episodes we witnessed although we did not witness chicks actually being eaten.

Frequent incidents of disturbance in 1997 possibly disrupted the small Northwest Rock colony to the point of abandonment. Several days of Common Raven activity at ESCB preceded the murre abandonment. It has been shown that breeding success is positively correlated with nesting density in murres (Birkhead 1977b, Spear 1993, Parrish 1995). Birkhead (1977b) also suggested that guillemots breeding at low densities were "uneasy" and spent more time watching for potential predators than did birds in larger groups. Although murres usually exhibit site tenacity, when faced with chronic poor breeding success and/or heavy disturbance and predation, murres may abandon sites or colonies entirely (Birkhead 1977b, Birkhead & Nettleship 1995).

Conclusions

Not possessing data prior to the 1995 Incident, we cannot definitively determine that the Incident contributed to colony instability, subsequent disturbance, and resulting lowered productivity at ESCB murre colonies that year. However, many of our observations seem to point in that direction. The Cliff Rock West and Face Rock colonies, abandoned for unknown reasons in years following the Incident, are not presently stable. Unfortunately we have no evidence that they were established or stable in years preceding the Incident. The colony on Northwest Rock is also not stable. It was first observed in 1996, but there is the possibility it was present in 1995 and abandoned since it was in such close proximity to the site of the Wayfarer wreck. Alternately, the Northwest Rock colony may have been a new colony resulting from birds leaving Cliff Rock West and/or Face Rock.

Given that seasonal and diurnal attendance patterns of Flattop, East, and Mid Rocks in 1996 and 1997 are similar, both between years and to other studies, it appears that these colonies are presently fairly stable. Attendance at breeding colonies increased from 1996 to 1997, yet we can only speculate if this was the result of higher numbers of murres returning each subsequent year after the Incident, or new colony growth. The 1995 cohort returning to ESCB colonies will be small due to low productivity in the year of the Incident. We may be seeing effects of a reduced 1995 cohort in the small 10% increase in attendance during incubation and nestling periods in 1997, the relative stability of overall numbers throughout the 1997 breeding season, and the absence of a non-breeder influx late in the 1997 season. However, we have no other productivity estimates to compare between years, and it is possible that due to a high level of disturbance, perhaps productivity is always low at the ESCB colonies.

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Table 1. Final model for covariance analysis (ANCOVA) of Common Murre attendance in May and June, 1996 & 1997.

source	df	partial SS	MS	F	prob>F
model	11	3054361.55	277669.23	215.45	0.00001
year	1	15311.73	15311.73	11.88	0.0008
date	1	32073.40	32073.40	24.89	0.00001
plot	2	24257.12	12128.56	9.41	0.0002
air temperature	1	9302.07	9302.07	7.22	0.0085
UI @ 39° latitude	1	23101.19	23101.19	17.92	0.0001
year * date	1	6371.16	6371.16	4.94	0.0285
year * plot	2	71834.98	35917.49	27.87	0.00001
plot * date	2	12650.17	6325.09	4.91	0.0093
residual	96	123723.05	1288.78		
total	107	3178084.60	29701.73		

Table 2. Models for covariance analysis (ANCOVA) of Common Murre attendance in May and June, 1996 & 1997, using only the atmospheric variables of (a) windspeed and (b) windspeed³ (=measure of ocean turbulence).

a.

source	df	partial SS	MS	F	prob>F
model	9	3030609.10	336734.35	223.77	0.00001
year	1	89413.32	89413.32	59.42	0.00001
date	1	39399.35	39399.35	26.18	0.00001
plot	2	24257.12	12128.56	8.06	0.0006
windspeed	1	6177.29	6177.29	4.10	0.0455
year * plot	2	71834.98	35917.49	23.87	0.00001
plot * date	2	12650.17	6325.09	4.20	0.0177
residual	98	147475.50	1504.85		
total	107	3178084.60	29701.73		

b.

source	df	partial SS	MS	F	prob>F
model	9	3030230.38	336692.26	223.16	0.00001
year	1	114810.37	114810.37	76.1	0.00001
date	1	37716.06	37716.06	25	0.00001
plot	2	24257.12	12128.56	8.04	0.0006
windspeed ³	1	5798.57	5798.57	3.84	0.0528
year * plot	2	71834.98	35917.49	23.81	0.00001
plot * date	2	12650.17	6325.09	4.19	0.0179
residual	98	147854.22	1508.72		
total	107	3178084.60	29701.73		

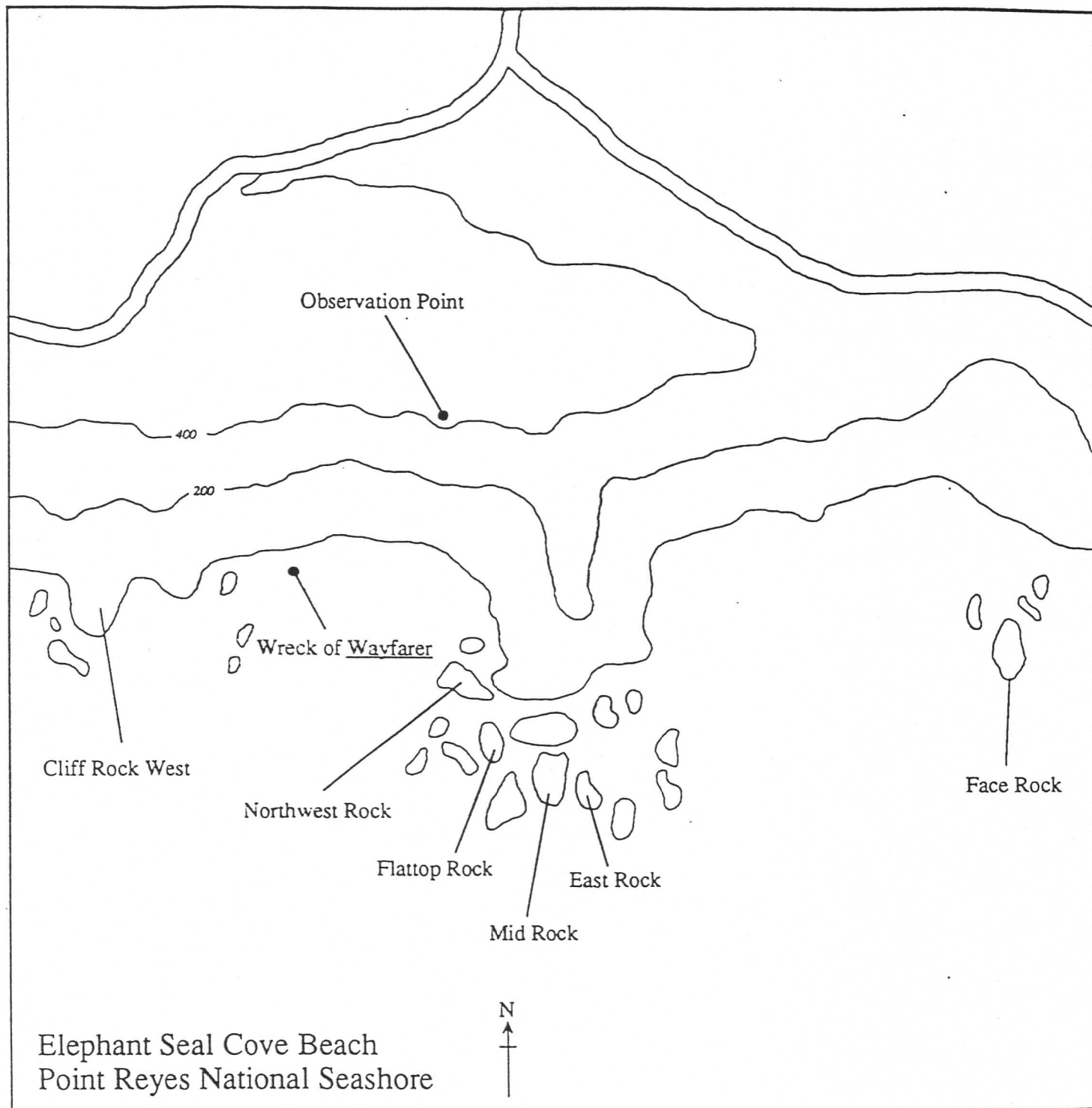


Figure 1. Elephant Seal Cove Beach area, Point Reyes National Seashore, Marin County, California. Site of the grounding of the Wayfarer, observation point, and monitored colonies are labeled. (Redrawn after USGS Drakes Bay Quadrangle.)

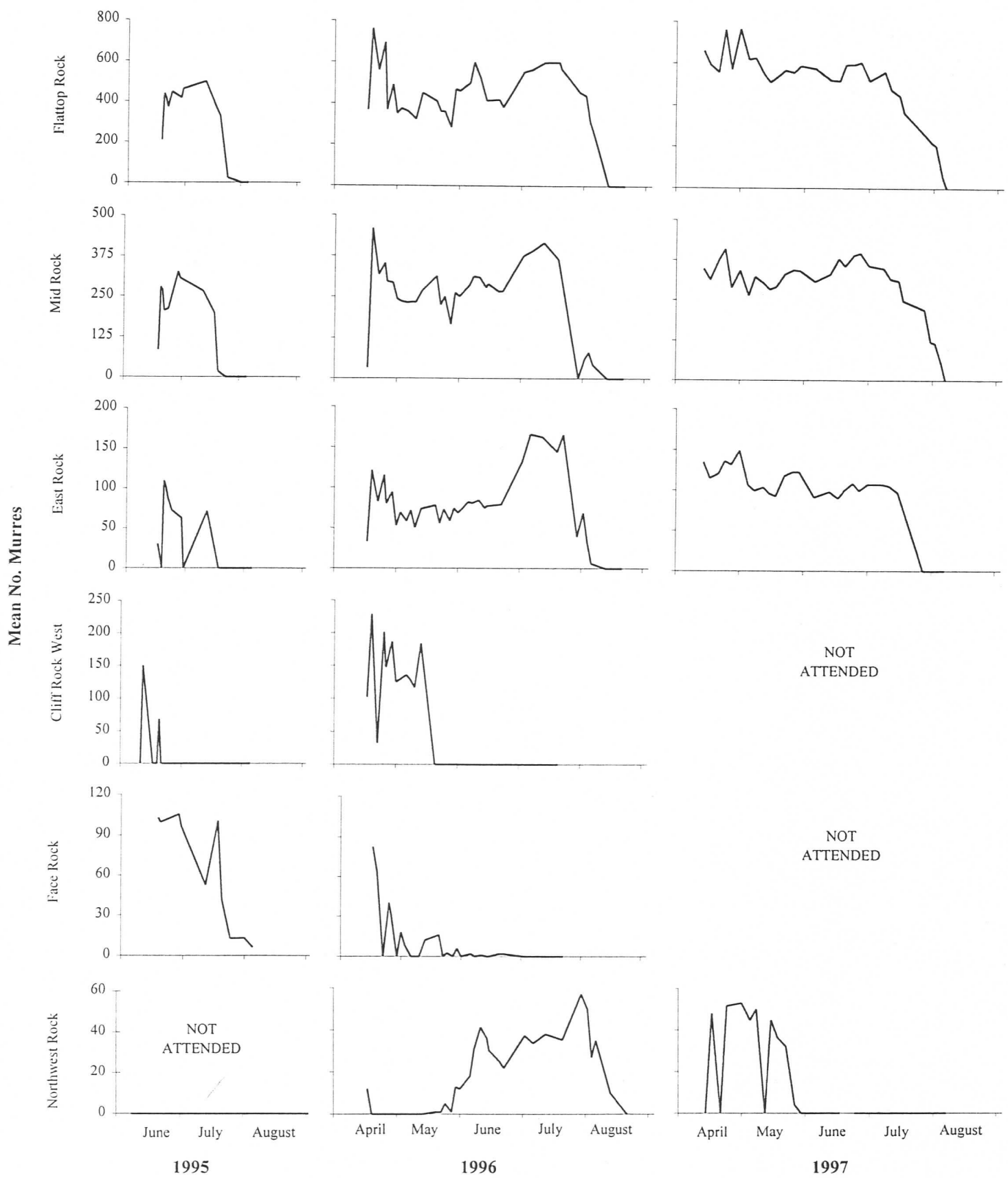


Figure 2. Seasonal attendance of Common Murres, 1995-1997. Attendance patterns are presented for each of the six colonies surveyed.

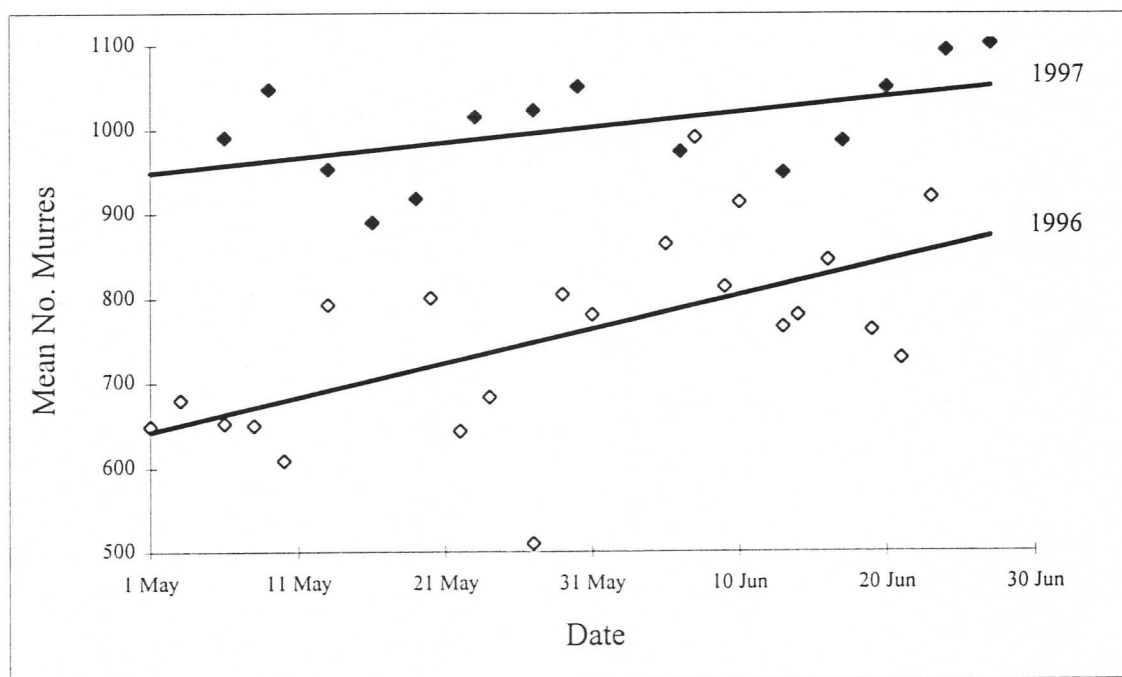


Figure 3. Attendance patterns of Common Murres in May and June, 1996 and 1997. Values are a total for numbers at Flattop Rock, Mid Rock, and East Rock combined.

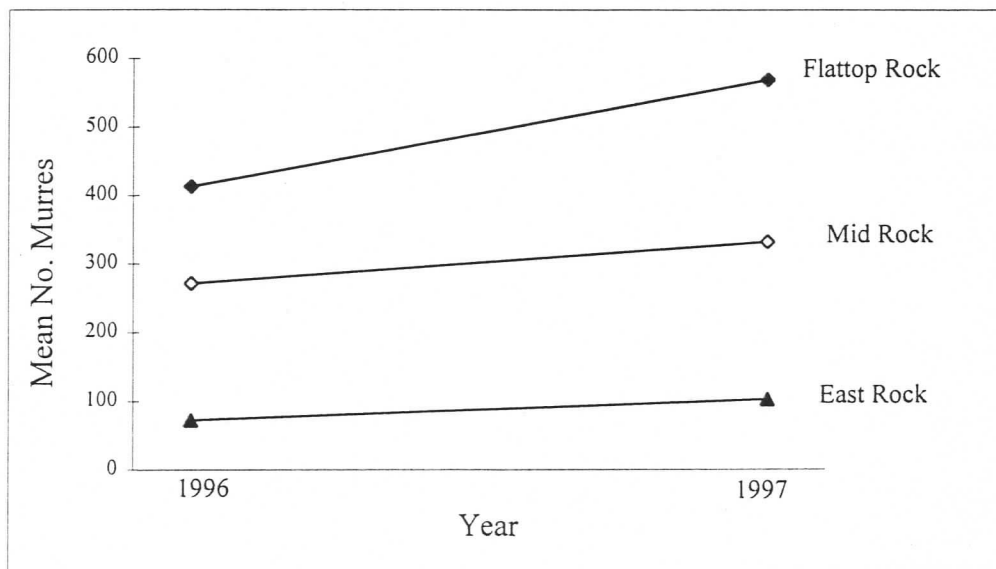


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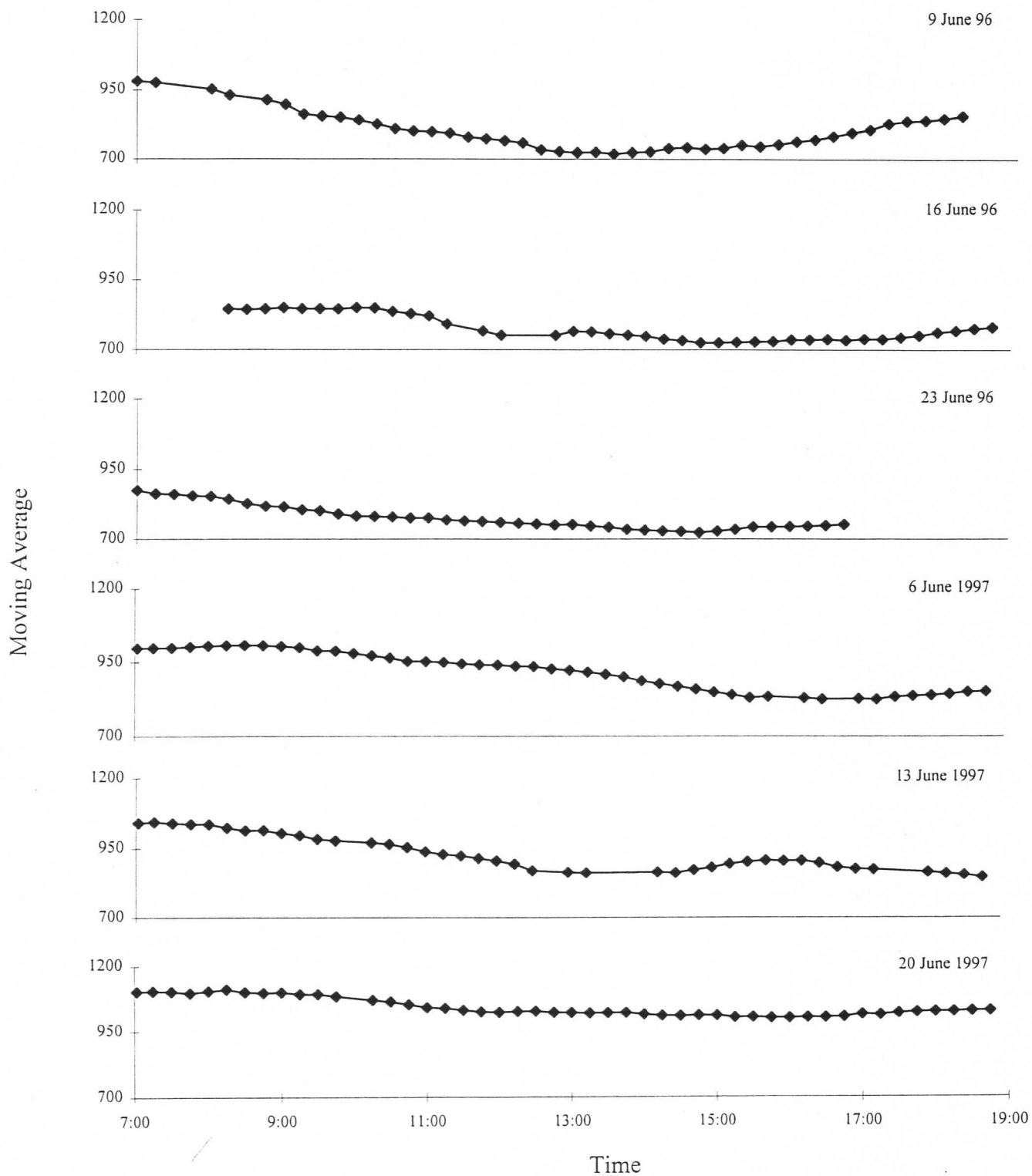


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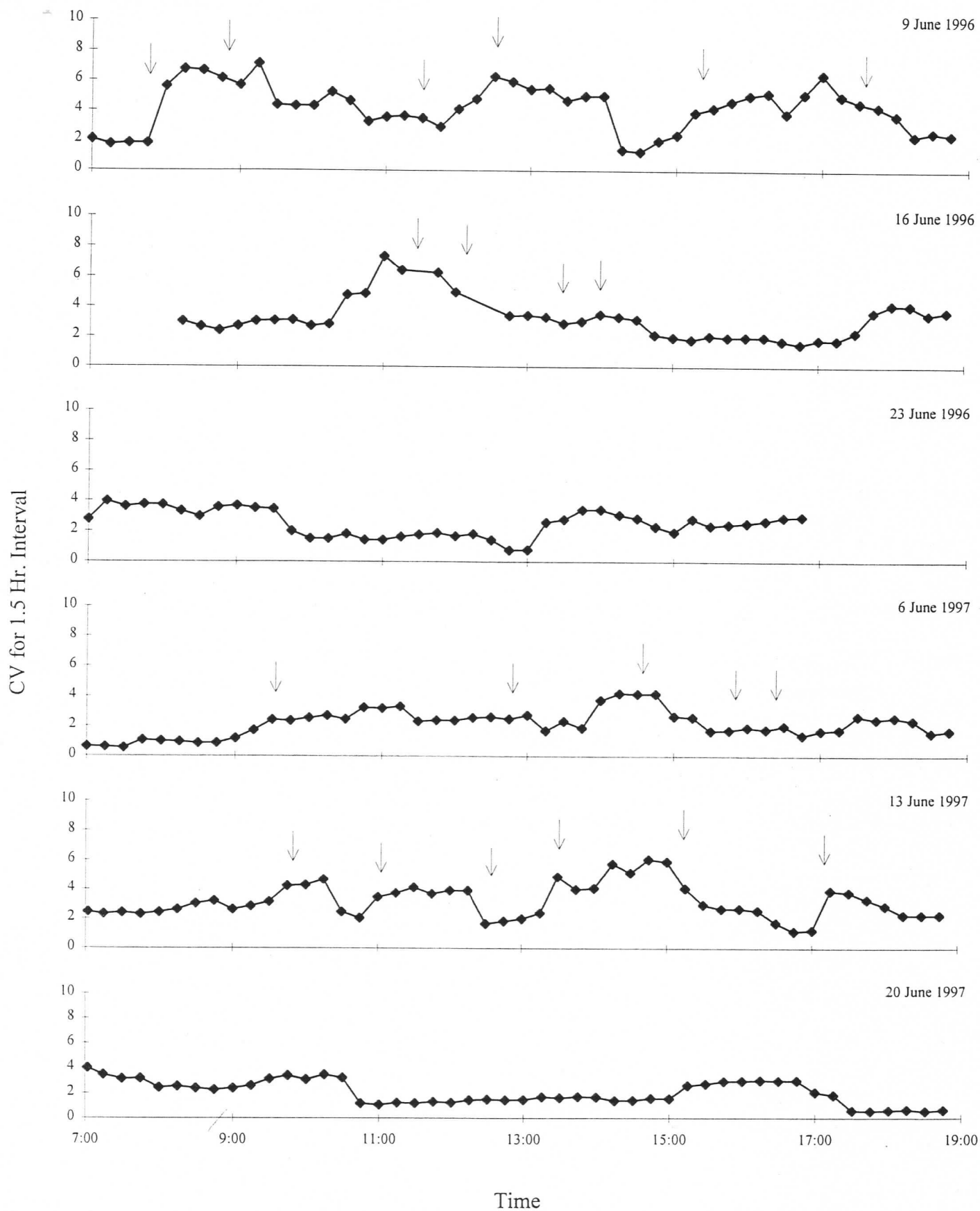


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