OBSERVATIONS ON A COMMON RAVEN *CORVUS CORAX* NEST ON REEF ISLAND, HAIDA GWAII

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SUMMARY

During May and June 2006, I observed a pair of Common Ravens (*Corvus corax*) nesting within an Ancient Murrelet (*Synthliboramphus antiquus*) colony on Reef Island, Haida Gwaii. In 59 hours of observation over a three-week period the ravens fed their chicks primarily Ancient Murrelet adults, using trees around the nest as short-term caches between feedings. The Ancient Murrelets are burrow-nesting seabirds that are only active on the colony during dark hours, raising questions about how and when the ravens are killing their prey.

INTRODUCTION

The Ancient Murrelet has been studied on Reef Island for the past 23 years (Gaston, 1992). Throughout this period, it was thought that predation by Common Ravens was responsible for many of the Ancient Murrelet carcasses distributed throughout the study area (Gaston, personal communication). In this study I set out to test the hypothesis that Common Ravens are important predators of Ancient Murrelets: I also collected information on the diet of the Common Raven in North America, on food caching, and on territorial behavior. In addition, I report on predatory behavior, on deceptive tactics used to conceal the whereabouts of prey, and on a possible example of tool use.

REVIEW OF PREVIOUS STUDIES

The Common Raven is cited as a scavenger and opportunistic feeder (Engel & Young 1989, Harlow 1922, Heinrich 1988, Murray 1945, Nelson 1934, Stahler *et al.* 1986, Stiehl & Trautwein 1991, Temple 1974, White 2004, Wilmers *et al.* 2003), and also a predator (Gaston 1992, Kelly *et al.* 2005, Maccarone 1992, Nelson 1934, Parmelee & Parmelee 1988, Temple 1974). Raven chicks are fed a wide variety of food by both parents (Murray 1945, Engel & Young 1989, Harlow 1922). Studies of Common Raven diet in North America over the last century demonstrate its diversity in North America. Large vertebrate species, rodents, birds, reptiles and a wide selection of insects figure prominently in these studies, as well as garbage, seeds, leaves and bark. The list includes species from over 39 families of vertebrates, arthropods, and mollusks. Studies from different regions report different, but not mutually exclusive, diets, demonstrating how opportunistic this bird is in its feeding. Steil and Trautwein (1991) explain differences in Raven diet between studies by pointing to local variations in availability of different food types.

Table 1
A review of the diet of the Common Raven based on North American studies over the past century

Vegetation				
		Region	**Food type**	**Citation**
		W Virginia	American holly *(Ilex opaca)*	Harlow et al., 1975
		SW Idaho	Barley	Engel and Young, 1989
		Pennsylvania mountains, SE Oregon, W Virginia, SW Idaho	Corn	Harlow, 1922; Nelson, 1934; Harlow et al., 1975; Engel and Young, 1989;
		W Virginia	Forbs and grasses	Harlow et al., 1975
		W Virginia	Hemlock *(Tsuga canadensis)*	Harlow et al., 1975
		S California	Livestock feed	Webb et al., 2004
		SW Idaho	Oats	Engel and Young, 1989
		SW Idaho	Russian olive	Engel and Young, 1989
		Pennsylvania mountains	Tree buds	Harlow, 1922
		SW Idaho	Wheat	Engel and Young, 1989
Animal Carrion, or unknown cause of death				
	Reptiles, amphibians, fish			
		SE Oregon	Carp (*Cyrpinus carpio*)	Stiel and Trautwein, 1991
		SE Oregon, SW Idaho, Se Oregon,	Fish	Nelson, 1934; Engel and Young, 1989; Stiehl and Trautwein, 1991
		Pennsylvania mountains	Frogs	Harlow, 1922
		SE Oregon	Horned toad (*Phrynosoma* spp.)	Nelson, 1934
		SW Idaho, SE Oregon	Reptiles	Engel and Young, 1989; Stiehl and Trautwein, 1991
		SE Oregon	Sceloporus lizards	Nelson, 1934
		Pennsylvania mountains, SE Oregon	Snakes	Harlow, 1922; Nelson, 1934
		SE Oregon	Spadefoot toad (*Scaphiopus hamondii*)	Nelson, 1934
		SE Oregon	Toad (*Bufo* spp.)	Nelson, 1934
	Mammals			
		W Virginia	Bat (*Chiroptera*)	Harlow et al., 1975
		W Virginia, SW Idaho, SE Oregon	Cow (*Bos taurus*)	Harlow et al. 1975; Engel and Young, 1989; Stiehl and Trautwein, 1991
		Pennsylvania mountains, W Virginia, Taiga forest, SE Oregon	Deer	Harlow, 1922; Harlow et al., 1975; Heinrich, 1988; Stiehl and Trautwein, 1991
		Pennsylvania mountains, W Virginia	Dog	Harlow, 1922; Harlow et al., 1975
		W Virginia	Domestic sheep (*Ovis aries*)	Harlow et al., 1975
		Taiga forests, Wyoming	Elk	Heinrich, 1988; White, 2004
		W Virginia	Goat (*Capra* spp.)	Harlow et al. 1975
		W Virginia	Hog (*Sus* spp.)	Harlow et al. 1975

W Virginia	House cat (*Felis domesticus*)	Harlow et al., 1975
Taiga forests	Moose	Heinrich, 1988
SE Oregon	*Mustela*	Stiel and Trautwein, 1991
SE Oregon, W Virginia, SE Oregon	Rabbit	Nelson, 1934; Harlow et al. 1975; Stiehl and Trautwein, 1991
W Virginia	Raccoon (*Procyon lotor*)	Harlow et al., 1975
W Virginia	Striped skunk (*Mephitis mephitis*)	Harlow et al., 1975
W Virginia	Virginia oppossum (*Didelphis marsupialis*)	Harlow et al., 1975
W Virginia	Woodchuck *(Marmota monax)*	Harlow et al., 1975
Rodents		
SE Oregon	*Ammosphermophilus leucurus*	Stiel and Trautwein, 1991
SE Oregon, W Virginia	Chipmunk (*Eutamias* spp.)	Nelson, 1934; Harlow et al. 1975
SW Oregon	Cricetidae	Stiehl and Trautwein, 1991
SW Idaho	Deer Mouse (*Peromyscus* spp.)	Engel and Young, 1989
W Virginia, SW Idaho	House Mouse (*Mus musculus*)	Harlow et al. 1975; Engel and Young, 1989
SW Idaho, SE Oregon	Kangaroo Rat (*Dipodomys* spp.)	Engel and Young, 1989, Stiel and Trautwein, 1991
SE Oregon	*Lagurus curtatus*	Stiel and Trautwein, 1991
SE Oregon	*Marmota flaviventris*	Stiel and Trautwein, 1991
W Virginia	Mole (*Talpidae*)	Harlow et al. 1975
SE Oregon	*Neotoma* spp.	Stiel and Trautwein, 1991
SW Idaho, SE Oregon	*Perognathys* spp.	Engel and Young, 1989; Stiehl and Trautwein, 1991
SE Oregon, SW Idaho	Pocket gopher (*Thomomys* spp.)	Nelson, 1934; Engel and Young, 1989
SE Oregon	*Reithrodontomys megalotis*	Stiel and Trautwein, 1991
Pennsylvania mountains, SE Oregon, SE Oregon	Rodents	Harlow, 1922; Stiehl, 1985; Stiehl and Trautwein, 1991;
W Virginia, SW Idaho, SE Oregon	Shrew (*insectivoria, Sorex*)	Harlow et al. 1975, Engel and Young, 1989; Stiel and Trautwein, 1991
SE Oregon	*Spermophilus* spp.	Stiel and Trautwein, 1991
SE Oregon	*Thomomys* spp.	Stiel and Trautwein, 1991
W Virginia, SW Idaho, SE Oregon	Vole (*Microtus*)	Harlow et al. 1975; Engel and Young, 1989; Stiehl and Trautwein, 1991
W Virginia, SE Oregon	White footed mouse (*Peromyscus* spp.)	Harlow et al. 1975; Stiehl and Trautwein, 1991
Other		
SE Oregon, SW Idaho, W Virginia, SE Oregon,	Birds	Nelson, 1934; Engel and Young, 1989; Harlow et al. 1975; Stiehl and Trautwein, 1991
SE Oregon, SE Oregon	Carrion	Nelson, 1934; Stiehl, 1985
W Virginia	Crayfish	Harlow et al., 1975
S California	Desert tortoise (*Gopherus agassizii*)	Webb et al., 2004

		W Virginia	Snail	Harlow et al., 1975
Insects				
		Pennsylvania mountains, SE Oregon, SW Idaho	Coleoptera	Harlow, 1922; Nelson, 1934; Engel and Young, 1989
		SE Oregon	Diaptera	Nelson, 1934
		SE Oregon	Heteroptera	Nelson, 1934
		SE Oregon	Homoptera	Nelson, 1934
		SE Oregon	Hymenoptera	Nelson, 1934
		W Virginia, SE Oregon	Insects	Harlow et al., 1975; Stiel and Trautwein, 1991
		SE Oregon	Lepidoptera	Nelson, 1934
		SE Oregon, SE Oregon, SW Idaho	Orthoptera	Nelson, 1934; Stiehl, 1985; Engel and Young, 1989
Live Prey				
		N British Columbia	Ancient Murrelet (*Synthliboramphus antiquus*)	This study
		N California	Black crowned Night-Herons	Kelly et al., 2005
		SW Alaska, SW Alaska, Newfoundland, Norway	Black Legged Kittiwakes (*Rissa tridactyla*)	Parmelee & Parmelee, 1988; Klicka & Winker, 1991; MacCarone, 1992; Tella et al., 1995
		SE Oregon, SE Oregon, N California	Eggs	Stiehl, 1985; Stiehl and Trautwein, 1991; Kelly et al., 2005
		N California	Great Blue Herons	Kelly et al., 2005
		N California	Great Egret (*Ardea alba*)	Kelly et al., 2005
		N California	Nestlings	Kelly et al., 2005
		N California	Snowy Egret	Kelly et al., 2005
Other				
		W Virginia	Aluminum foil, cloth, paper, plastic, rubber, etc..	Harlow et al., 1975
		S California	Landfill, sewage	Webb et al., 2004
		W Virginia	Stones (quartz, shale, sandstone)	Harlow et al., 1975

Engel and Young (1989) report inter-seasonal variation in Common Raven diet in Idaho. They found, through pellet analysis, that raven predation of birds peaks in spring, although Nelson (1934) showed that in June, less than 10% of stomach contents of ravens were made up of birds, the majority of their diet being small mammals (rabbits mostly) and insects.

Kelly *et al*. (2004) reported that energy obtained by ravens exploiting heronries in California represent at least 76% of their daily energy requirement. Relative frequency of predation of adult Snowy Egret, Black crowned Night Heron and Great Blue Herons was related to size, with the smallest being the most likely prey. This study indicates that the rate of depredation of nests for eggs and nestlings of ardeids is correlated to Common Raven brood size, suggesting that manipulation of their reproductive success could be a viable management solution for heronries.

Predation of eggs, nestlings and adult Black legged Kittiwakes, a colonial seabird, has been reported in Alaska and Newfoundland (Klicka & Winker, 1991; MacCarone, 1992; Parmelee & Parmelee, 1988; Tella *et al.*, 1995). Tella *et al.* (1995) suggest that ravens depend on predation of Black legged Kittiwakes for most or all of their energetic needs. Gaston and Elliot, (1996) report predation of Thick-billed Murre eggs and nestlings on cliff colonies in Nunavut.

Ravens are known to cache food (de Kort & Clayton, 2006), usually small, expensive food packages for short periods (Gwinner, 1965 in Bugnyar & Kotrschal, 2002). While caching around conspecifics, ravens display observational learning and deceptive tactics, such as the use of large objects to conceal information on cache location (Bugnyar & Kotschal, 2002).

STUDY AREA AND METHODS

Study area

Reef Island has been studied since 1983, when the Canadian Wildlife Service first surveyed the Ancient Murrelet colony (Gaston, 1992). The island continues to be a site for studies on the Ancient Murrelet, songbirds, and vegetation browsing by the Sitka Black-tailed deer. The island is situated in Laskeek Bay, British Columbia (52”52’N, 131”31’W). It is 4 km long and 1.6 km wide and is located about 7 km off the coast of the main archipelago (Gaston 1992). It is mainly covered with dense primary coastal temperate rainforest, with predominantly Western Hemlock *Tsuga heterophylla* and Sitka Spruce *Picea sitchensis* and some Western Redcedar *Thuja plicata* and Red Alder *Alnus rubra*. The study site was situated on the north side of the island, extending from a ridge approximately 300 m inland down an average 45° slope to the coast (Gaston 1992). The terrain includes some sheer cliffs.

The only mammalian predators are the River Otter (*Lutra canadensis*), of which we found some evidence in the study area, and deer mice (*Peromuscus maniculatus*), both indigenous to Reef Island. We found no evidence of the other mammalian species indigenous to Haida Gwaii, which include two species of shrew, ermine, pine marten and black bear. There were few signs of browsing by the Sitka Black-tailed Deer *Odocoileus hemionus* which is an invasive species modifying the habitat of most islands in the archipelago. Reef Island has had multiple deer culls since the late 1990’s, resulting in low deer population densities and gradual regeneration of the forest’s natural vegetation (A.J. Gaston, personal communication).

Cassin’s Auklet *Ptychoramphus aleuticus* nests in the study area at a lower frequency than the Ancient Murrelet. Bald Eagles *Haliaeetus leucocephalus* also nest in the study area. As many as six Bald Eagles could be seen at any time during the day, circling above the study area. The Northwestern Crow *Corvus caurinus* is common in the area, feeding primarily in the intertidal zone (Gaston 1992).

Observations of ravens

Observations were made in May and June 2006; and involved a single pair of Common Ravens with nestlings. A second pair of Common Ravens was

discovered more than 1.5 km away from the nest of pair under study. Chicks associated to the second nest were never observed, although their presence was inferred by evidence such as defecation remains under the nest. A Common Raven nest in the current location was observed during previous field seasons (A.J. Gaston, personal communication). The nest was conspicuously located at a height of 21.4 m in a mature, gnarly, 51.6 m tall Sitka Spruce which stands in an area where, along with natural burrows Ancient Murrelets also occupy a number of artificial nest boxes. The boxes were surveyed daily for activity by other members of the field camp.

I erected a temporary blind 45 m from the nest, on top of the ridge running the length of the island. It afforded a view of the nest from 15° below it, from which any activity at the nest site could be seen easily. From the blind one could observe the adults' direction of arrival, and most activity in the general vicinity. Observation of the nest began as early as 04:00 and ended as late as 21:00. After the first three days the blind became redundant because the birds had become accustomed to the presence of an observer.

The Ancient Murrelet is a seabird that only arrives at and leaves the colony under cover of darkness. To determine whether there was temporal overlap between the activity of the Common Ravens and the Ancient Murrelets, observers stationed along the colony before sunrise noted the time of the last Ancient Murrelets departures while I watched the Common Ravens on their roosts near the nest until they became active. The dawn watch began in the complete darkness before 4 AM and concluded at 6:30 AM.

Census of Ancient Murrelet burrows

A census of Ancient Murrelet burrows was conducted along five North-South transects (A, B, C, D, E, Fig 1), running from the coast to the inland edge of the colony. All burrows were counted in circular plots 5 m in diameter (area = 78.5 m^2). The first plots were placed either at 5 m or 30 m from the shore, alternating between transects. The plots were 50 m apart, and transects were every 100 m (excluding transect E, which was 50 m from transect D due to terrain constraints). Ancient Murrelet burrows were distinguished from Cassin's Auklet burrows by smell, since Cassin's Auklet burrows have a strong and recognizable odor. Along each transect number and type of predations (feather pile, wings, bones) were recorded within 5 m on either side of each transect. Transects were terminated at the edge of the colony, which was determined by inspecting the adjacent area for burrows.

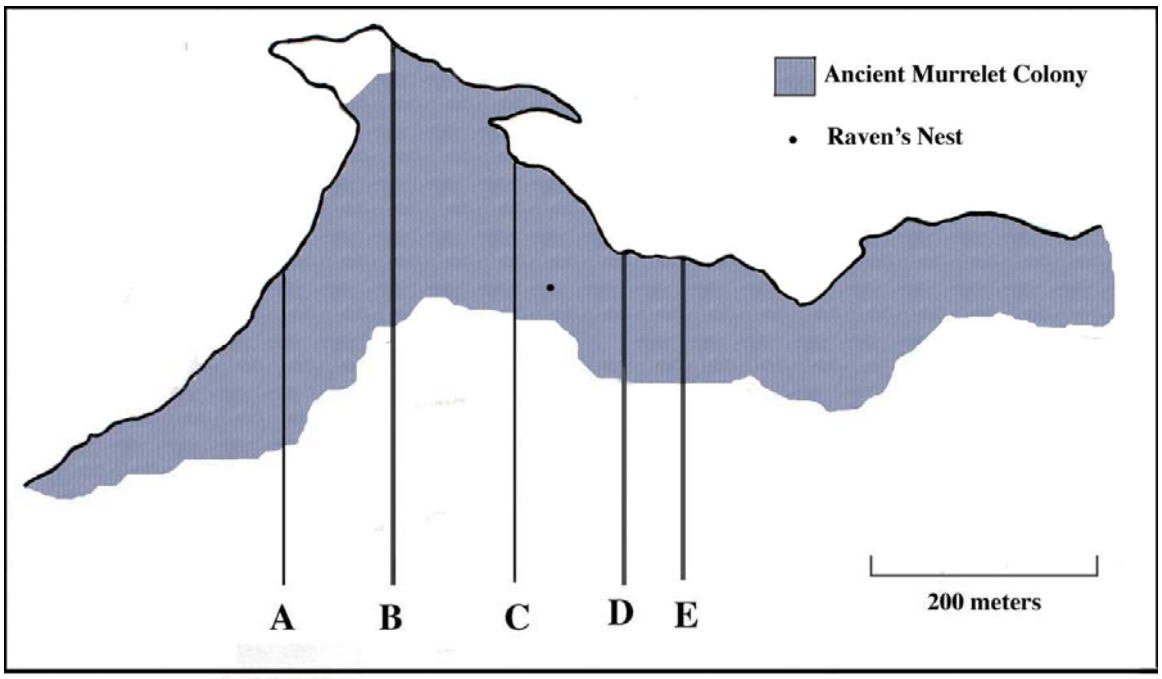

Fig.1
View of Raven's nest with respect to the census transects (A, B, C, D, E) and the Ancient Murrelet colony

RESULTS

Behaviour at the nest

The Common Raven pair under study had three nestlings when observation began on 20 May. The raven pair was initially disturbed by our presence near the nest, and no feedings occurred on the first morning of observation. However, by the afternoon, when a blind had been erected, the Common Raven pair had ceased alarm calling and fed the chicks twice.

By the second day of observation, the two adults could be differentiated by sight due to differences in beak anatomy. The bird denoted as A has a longer and more curved bill, whereas B's bill had a distinctive knob on the top due to plumage. Observations of incubation behaviour by the same pair in 2007 confirmed that A, which undertook most or all incubation, was the female. A was seen cleaning the nest cup, whereas B was not. The nest cup was cleaned after defecation by the chicks, which often occurred after a feeding. Common Witch's Hair (*Alectoria sarmentosa*), was removed and replaced by A on many of the observed cleanings. Some nest cleanups took as long as 5 min., and involved removing and replacing sticks and lichen contaminated with feces (samples were recovered from where they were dropped more than 100 m from the nest).

Food caching

On the second day of the study, immediately following harassment by a Bald Eagle, one of the ravens was observed bringing the carcass of an Ancient Murrelet to the top of a nearby over-mature spruce. The raven proceeded to pluck its prey, sending a cascade of feathers to the ground. On subsequent days, similar cascades of feathers allowed me to identify three other cache trees, all of which were used on a regular basis to pluck and/or temporarily store Ancient Murrelet carcasses. The four

'cache' trees identified were all within 100 m of the nest (Fig. 2). All cache trees were similar to the nest tree in that they were among the largest and most moss laden Sitka spruce or Western hemlock in the vicinity. Arrival to a cache tree with an unplucked carcass was only observed once.

When approaching a cache tree, bird A would fly to a low branch on a nearby tree and perch while B called loudly and repeatedly. Bird A would then gradually ascend by hopping from branch to branch to where the carcass was cached, always on a large moss laden branch. It would pluck the carcass, holding it down with one foot, plucking and tearing at flesh with the beak. After a few mouthfuls were consumed, it would fly to the nest and pass by beak or regurgitate to one or two chicks. Feedings of this nature often occurred in bouts of three to five feedings over a ten minute period. Only the remains of adult Ancient Murrelets were seen being fed to the nestlings.

The ravens arrived from three general directions, denoted X, Y and Z (Fig. 2). The likelihood that an arriving bird would be carrying food was approximately equal for all three directions, although Z was the most used. Crows were chased by ravens to the East, following the path Z. Eagles arrived from Y most often, and left between Z and X.

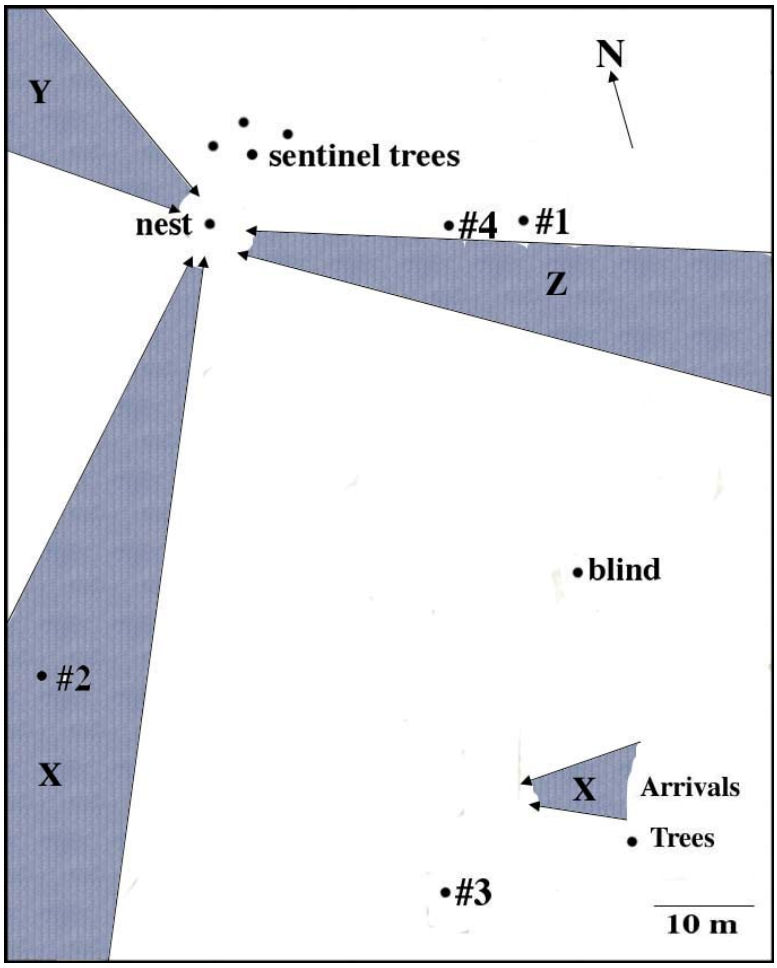

Fig. 2
View of study site showing the position of the nest and cache trees (#1, #2, #3, #4) and directions of arrivals (X, Y, Z)

The ravens were observed driving off Northwestern Crows and Bald Eagles. On one occasion, while I observed B plucking and tearing off pieces of meat from an Ancient Murrelet carcass in cache tree #1, three people arrived in the vicinity of the nest. B silently left the cache, to alarm call from the sentinel trees (Fig. 2). At the same time, a crow, evading B's notice, perched in cache tree #1 and picked at the carcass, then moved to an older cache in Y and fed on the remains there. The crow moved between cache trees for 15 minutes before leaving the area undisturbed by the raven. B was within my sight and preoccupied by the group of humans the entire time. B was observed snapping twigs and dropping them when humans were present. On several occasions Bald Eagles (both adults and juveniles) perched within 10 m of the nest, remaining there until the adult ravens drove them away. The chicks would crouch down in the nest, invisible to me, when this occurred.

The pre-dawn observation of the colony and roosting ravens revealed that all the Ancient Murrelets had departed from the colony by 04.20, while the ravens did not leave their nightly perches until 05.15. The ravens had a relatively constant rate of feeding throughout the day, with a slight increase in the morning and before midday (Fig. 3).

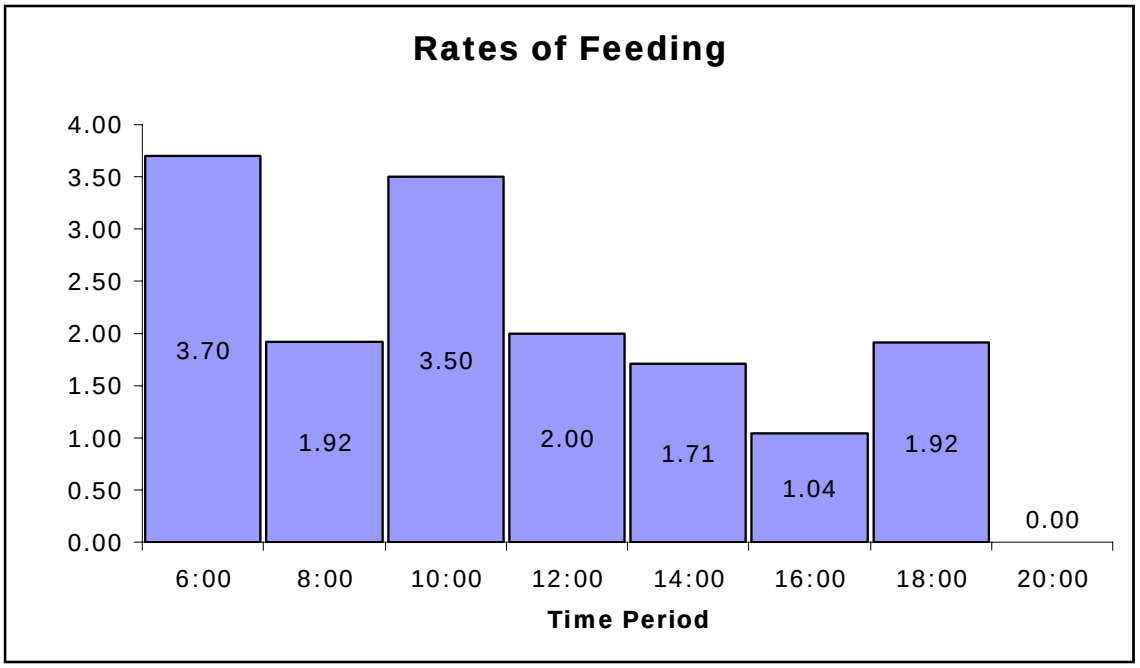

Fig. 3
Number of feedings in two hour intervals averaged over 12 days.

Census Results

We found 104 burrows and evidence of 51 predations on the five transects. There was a weak positive Pearson correlation between the number of burrows in a plot and number of predations in the plot and around it (Pearson r = 0.383, P (2-tailed) = 0.064).

Feathers at a burrow entrance and evidence of digging indicated that a breeding burrow had been dug up and the adult depredated. Eleven such cases were documented during the study period: two during the census on transects and nine prior to the census.

DISCUSSION

Observation of the Reef Island raven pair confirmed that they were responsible for many of the Ancient Murrelet carcasses scattered around the study area. Ancient Murrelet adults are the primary food source for raven chicks. These results raise questions about the means by which the ravens take the Ancient Murrelets, as the two species are active on the colony at different times of day. Along the census transects, only two burrows showed evidence of digging, but 51 predations were found along the transects. Ancient Murrelets occasionally use shallow burrows where they are not completely concealed (Gaston 1992), which would allow easy access to ravens. However, I did not observe any such easily accessible Ancient Murrelets in my exploration of the colony, an indication of the disadvantages of that kind of behavior.

Ravens are capable of learning, planning ahead and taking advantage of situations (Fritz & Kotrschal 1998, Heinrich 1999) and have the capacity to solve novel problems relating to food acquisition (Heinrich & Bugnyar 2005). Also, they can use olfaction in food location (Harriman & Berger 1986). This raises the possibility that the ravens were locating their prey by smell and dragging them out of burrows. This hypothesis is supported by a single observation (when the ravens were unaware of my presence) of the two ravens on the ground hopping around in an area of high burrow density in the early evening.

The ravens arrived at the nest site most frequently from areas of high burrow density on the colony (Fig. 2). By flying directly and silently to a cache tree, they could either evade my notice or use trees to block my view of them, making it impossible to see anything in their beaks. This behavior occurred throughout the day, suggesting that they were killing Ancient Murrelets during the day, when the only birds present at the colony were in their burrows.

Common Ravens are certainly capable of killing birds the size of Ancient Murrelets: they have been observed killing the larger Black-legged Kittiwake (*Rissa tridactyla*) in Alaska (Klicka & Winker 1991, Parmelee & Parmelee 1988) and in Newfoundland (MacCarone 1992). While Parmalee and Parmalee (1988) reported dive-bombing tactics, Klicka and Winker (1991) described face offs between ravens and gulls at the nest site. In these situations the seabird prey is exposed on the nest, during the day, making them easy targets. How this behavior is adapted to burrow nesting birds needs further research.

Ravens are known to depredate heron nests, most often between 10.00 and 14.45 h (Kelly *et al.* 2005). Engle and Young (1989) found that during spring and summer months, ravens foraged primarily in the morning and evening. MacCarone (1992) reported that patrols occurred at a constant frequency throughout the day. This corresponds with the results from this study, where ravens plucked Ancient Murrelet carcasses throughout the day.

According to de Kort and Clayton, (2006), the common ancestor of corvids was a cacher, and both the Common Raven and the Northwestern Crow are considered moderate cachers. The ravens at Reef Island did cache regularly throughout the study, using specific cache trees as indicated in Fig.2. Observation revealed that crows have the capacity to raid raven caches, when given the opportunity. This may be the basis behind the secretive behavior observed when the ravens were accessing their caches. The twig snapping behavior observed supports Heinrich's hypothesis that corvids dislodge objects as a displacement

behavior when they are agitated (Heinrich, 1988).

This study has raised as many questions as it has answered, leaving an opening for future research. Delving into the mysterious ways of the raven is a challenge. However, the ravens on Reef Island provide a particularly good opportunity to study their predatory behavior. Not only is the nest well-positioned for observation, but the pair seemed uncharacteristically unfazed by human presence, once they became accustomed to it.

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