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THE DAILY MOVEMENTS OF CORMORANTS ON SAN FRANCISCO BAY

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The daily movements of large flocks of cormorants from their roosting sites to fishing areas are so spectacular that they have received attention from many authors (see, for example, Murphy, 1936:904; Beebe, 1938:38-42; Brewster, 1883:395). Because these movements usually are extensive and the areas concerned remote, no detailed studies of them have hitherto been made.

In order to work out as completely as possible the roosting activities, fishing activities, and daily movements of non-breeding cormorants, a restricted area approximately thirty square miles in extent was selected. This area lies in the east-central part of San Francisco Bay, California, between the approach to the San Francisco-Oakland Bay Bridge and Castro Point (see fig. 1). It is surrounded on three sides by highways and is bisected by the Berkeley Pier so that all parts are readily accessible to an observer. Two species of cormorants, the Brandt (*Phalacrocorax penicillatus*) and the Double-crested (*Phalacrocorax auritus albociliatus*), occur here.

Whenever possible observations were made from dawn until dusk in order to obtain a complete story of the daily activity. Study was begun in September, 1940, and continued through July, 1941. The fishing activities of Double-crested Cormorants on San Francisco Bay have been described in a previous paper (Bartholomew, 1942).

I am indebted to Dr. Alden H. Miller for advice and suggestions in the preparation of this paper and to George A. Bartholomew, Sr., for the preparation of the illustrative material.

DEPARTURE FROM THE NIGHTTIME ROOST AND FLOCK FORMATION

The nighttime roost of all the Double-crested Cormorants on the east-central part of San Francisco Bay is the Brooks Island power line (see fig. 1) which was put in service on April 4, 1923. This line runs from the east shore of the Bay, one-quarter of a mile north of Point Isabel, Contra Costa County, to Brooks Island, a distance of slightly more than one and nine-tenths miles. The twelve towers are eighty-four feet high and stand on concrete platforms which rise three feet above high-tide level. Each is equipped with three cross arms. The vertical distance between wires is four feet. The horizontal distance between the several sets of wires is eight to ten feet. The distance between towers is about 800 feet.

These large awkward aquatic birds roost on this power line like blackbirds on a telephone wire. The obvious disadvantages of the precariousness of the perch and the exposed nature of the roost are offset by several real advantages. In a busy harbor such as San Francisco Bay it is difficult for cormorants to find an adequate roosting site that is completely free from disturbance by man. Brooks Island is uninhabited, and the water over which the power line runs is so shallow that it can be used only by the smallest of pleasure boats and even these avoid it.

When sleeping on the wires, a cormorant stands erect, grasps the wire with both feet, twists its head around to either right or left and places it on its back in such a manner that the bill but not the entire head is covered by one of the wings. Upon

awakening, it stretches and sometimes preens a little. If the morning is windless, the birds may face either north or south (the only possible directions on the power line), but if there is even a slight breeze, all of them will be facing it as nearly as their perch will allow.

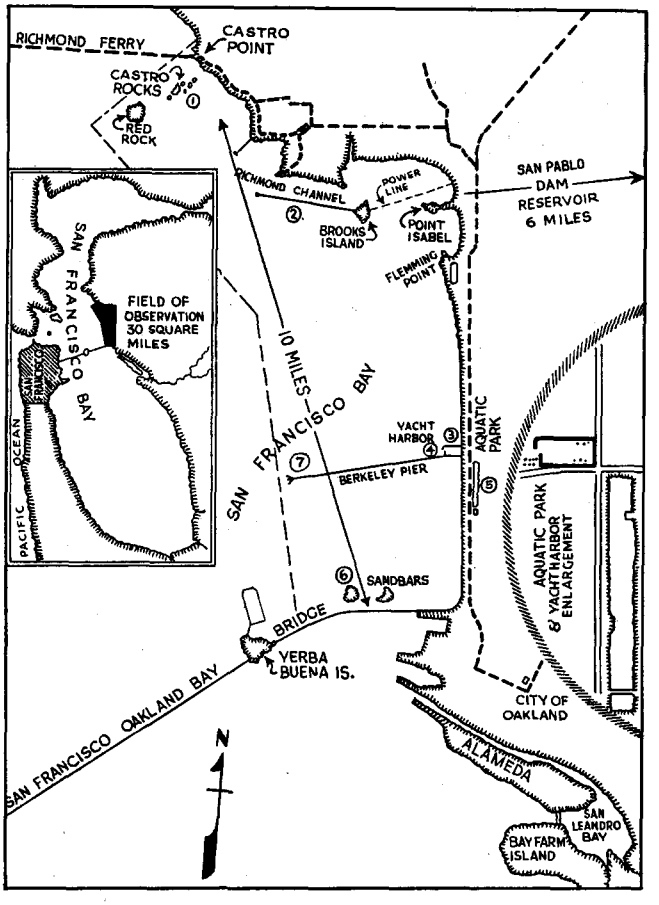

Fig. 1. Map of area of study. Circled figures indicate locations of daytime roosting sites of cormorants.

When a cormorant is about to leave the power line, it partly extends its wings, thrusts its head forward slightly, crouches down, leans forward, and then launches itself into the air. In taking off from the wires, the birds do not jump upward, but rather outward and downward so that they head toward the water at an angle about thirty degrees below horizontal. Instead of gliding down as one would expect, they fly downward with steadily beating wings, to level off just above the water and fly away usually less than five feet above the surface. On calm days their wings may come within six inches of the water, but on windy days they fly several feet higher to avoid the crests of the waves.

As a general rule, when a cormorant leaves the power line it does not immediately return, but flies directly away to spend the day on some other part of the Bay. Individual birds, however, will sometimes fly out a short distance without going much below the level of the wires, circle, and return and perch at some point near where they had

spent the night. At times this performance is common and at other times it is not seen at all. On the morning of January 24, 1941, before the general exodus began, this departure and return was frequent. Individuals repeatedly left the wires as if they were off for the day's fishing, but after flying for from 200 feet to 300 yards, they would circle and return to the roost again. As many as 40 birds from the vicinity of one tower would often be in the air at one time.

Typically the cormorants do not leave their roost *en masse* or even as flocks, but as scattered individuals or in groups of two to eight. The departure is not limited to any segment of the power line; birds can be seen dropping down toward the water along the whole extent of the roost. Virtually all the departing birds fly away in the same direction. Even when there were more than 2000 individuals on the roost, never more than twenty would fly away in a direction other than that followed by the main group.

After the individuals and small groups have dropped down near the water and flown 150 to 200 yards from the power line, one bird will be joined by another and this pair will attach itself to another group of two or three. The resulting small flocks will join other groups, until by the time the birds are one-half to three-quarters of a mile from the roost, flocks of fifteen or twenty are the rule. The merging of small flocks takes place in two ways: first, one flock may actually accelerate and overtake another, and second, two flocks flying along side by side may veer in toward each other and coalesce. The overtaking is most frequently done by individuals or groups of half a dozen or less.

When a flock of fifty or more catches up with another large flock, the overtaking is accomplished, fortuitously, by a slowing down of the flock ahead. This is caused by an interruption of the steady regular flight of the individuals comprising it. The birds execute a short, steep upward glide, which results in a stall followed by a brief interval of back paddling and then a drop back down near the water and a resumption of the normal wing beat. The maneuver is usually initiated by the leading members of a flock and is then imitated by the others in such a way that a sharp undulation passes through the flock from front to rear. Since this results in a marked decrease in the speed of the flock, it is overtaken by any group flying along close behind at a normal speed. The stalling, however, is independent of the presence of an overtaking flock, for it often takes place in isolated groups. Stalling has been observed only in flocks flying close to the water and seems to be elicited by two sets of circumstances: first, the organization of a flock into a definite formation, and second, the rising above obstacles such as driftwood, buoys, breakwaters, and piers.

By the time the cormorants are one and one-half to two miles from the roost, flocks containing as many as 150 or 200 individuals may be formed. Coalescence to form sizeable flocks is not, however, an invariable rule. Flocks may contain as few as two or as many as 300 members and an individual bird may even fly all the way to the feeding grounds by itself.

The merging of flocks to form larger and larger aggregations can continue only up to a certain point, for flocks can merge readily only when they are flying side by side or close behind one another. If one flock is a quarter of a mile ahead of another and both are flying in the same direction at approximately the same speed, the two are obviously not in a position to join forces. Because of this, flocks do not ordinarily continue to increase in size after they have flown two miles from the roost.

When flocks first form, they are compact, but are confused and unorganized; gradually they assume a definite formation. The smaller flocks of ten to twenty usually form a straight line with one bird directly behind the other, or a single file with each bird slightly to one side of the bird ahead; the line may be offset to either right or left. The

larger flocks tend to assume an asymmetrical "V" formation, but exceptions are frequent.

The mechanism by which a definite formation is assumed is so flexible that it is difficult to analyze. Immediately after the merging of two flocks, the birds form an unorganized mass, with some birds losing altitude, and others gaining it, some stalling, others gliding and still others swerving to right or left, but nevertheless, the group as a whole moves in the same direction as before, although at a reduced speed. The "V" formation usually develops within forty to sixty seconds after the coalescence. The birds in the middle of the flock gradually move to the edge and form the two arms of the "V." When a flock has assumed its formation, whether it be a single line or a "V," the birds are in a single file. They are not, however, always all at the same level because there is considerable vertical movement, especially in flocks which contain more than fifty or sixty birds. If one bird moves upward a few feet, the one behind it will follow suit, the next does the same and an undulation passes through the entire flock. These undulations usually start at the apex and move simultaneously down both arms of the "V," but sometimes, they start near the apex and move down only one arm. By the time an undulation reaches the middle of the formation, the birds which instigated it have returned to their original positions.

The speed of an organized flock exceeds that of an unorganized one. I have had two opportunities to measure the speed of flocks of cormorants. Both measurements were made from an automobile on birds flying south parallel to the Bay Shore Highway north of the east approach to the San Francisco-Oakland Bay Bridge. The first time, the flock, which contained about thirty-five birds, was flying at a slight angle to the highway so that it was impossible to measure the speed exactly. As nearly as could be estimated from the speedometer, the flock was moving twenty-five miles per hour. The other flock whose speed was measured contained approximately 140 cormorants and was flying about fifteen feet above the water, seventy-five yards west of the highway. When first seen it was in the process of reorganization, with some of the birds gliding and others stalling or shifting positions. The reorganization lasted while the flock traveled approximately one-quarter of a mile and during this period the speed of the flock as a whole varied from twelve to fourteen miles per hour. Suddenly the reorganization was completed and the speed of the flock almost exactly doubled. For the two miles that I was able to parallel its course, its speed varied from twenty-four to twenty-eight miles per hour.

Although the gradual departure from the roost described previously is the usual method of leaving the power line, the cormorants occasionally leave almost as one bird. Typical of these sudden departures was the one observed on December 21, 1940. When I arrived at Point Isabel at 6:20 a.m. it was still dark. The night had been a disagreeable one with continuous rain and wind, but in spite of this, all of the 2300 cormorants had remained on the power line. At 6:52, just after it was light enough for me to count the cormorants, the departure began. As if at a given signal, all of the 1500 or 1600 birds grouped around the five towers farthest from the east shore of the Bay literally exploded into the air. There was an actual cloud of cormorants about the power line. They milled about haphazardly for an estimated ninety seconds and then streamed away southward. In leaving the power line they did not immediately drop down toward the water as they do when the departure is gradual. Instead they maintained their original altitude for a minute or so and circled about before dropping down and flying away.

Although every one of the 1600 birds around the towers farthest from the shore had departed suddenly and simultaneously, the 700 cormorants on the towers nearer shore

remained undisturbed. Twenty minutes after the departure of the first group, the remaining birds became active. Scattered individuals flew out, circled, and returned to the power line to resume their roosting. By 7:15 the second departure was well under way, but this time the birds left gradually, with individuals and small groups dropping from the wires and angling sharply toward the water.

On March 14, 1941, another sudden departure was observed. The total number of birds on the power line this time was only about 950. At 6:15 a.m. they began to leave, not as individuals or small groups, but as flocks of from 100 to 500, all the members of any one group leaving the wires simultaneously. The cormorants around one tower or around two adjacent towers would leave at the same time. The behavior of a group of 500 (largest flock to leave as a unit) was typical of the mode of departure. This group appeared to explode into the air, but instead of milling about or dropping down toward the water, the birds immediately flew away south-southwest without delay or loss of altitude. By the time they had flown 400 yards they were 150 to 175 feet in the air and they maintained this altitude for as long as they were in sight. For the first quarter of a mile the flock was just a confused mass of birds, but by the time they were a half mile away they had formed a thick, unwieldy, asymmetrical "V." The arms of the "V" continued to thin out and straighten so that by the time the birds had reached Point Fleming, one and one-quarter miles south of the roost, the flock, despite its huge size, had assumed the characteristic "V" formation. By 6:45 all but fifty of the cormorants had left the power line and these departed as scattered individuals.

There is no apparent reason why the cormorants should vary their method of departure in this manner. In the case of the sudden departure on December 21, however, the causal factor could very well have been the storm which had been in progress during the night. The cormorants, because of the unprotected nature of their roost, were exposed to the full force of the wind and rain. After spending an uncomfortable night on their precarious perch of swaying wires, they were probably more than ready to leave just as soon as it was light.

As previously stated, virtually all the cormorants fly in the same direction when leaving the power line. The only exceptions to this are the flight of a few scattered individuals northwestward to the vicinity of the Castro Rocks off the tip of Point Richmond and the flight of small numbers eastward over the Berkeley Hills to the San Pablo Reservoir which lies near Orinda six miles east of the Brooks Island power line. The first of these movements involves individual birds flying west-northwest up the Richmond Channel and an observer is hardly aware of it unless he is on the tip of Point Castro to watch the cormorants arrive. The second movement is, however, a more significant and conspicuous variation, in as much as it involves small flocks rather than individuals and is directed away from San Francisco Bay. This eastward movement apparently does not occur every day, but it was seen on five separate days, all between September and January. The number of birds taking part in the flight on the various days varied from three to twenty-four.

It is impossible to tell whether the same birds flew east over the hills each time, but it seems probable that at least some of the birds did it repeatedly. My reasons for thinking this are two: first, the birds always left from the towers at the east end of the power line and these are the ones on which a bird returning from the east in the evening would logically alight, and second, in order to reach the San Pablo Reservoir, the cormorants must rise from sea level to an altitude of more than 1000 feet and cross the Berkeley Hills, so it seems probable that only a bird which had previously been to the reservoir would know how to reach it.

THE RETURN TO THE NIGHTTIME ROOST

The return of the cormorants to the Brooks Island power line in the afternoon and evening is not as spectacular as the departure in the morning, but it follows a more constant pattern. The return usually begins in the early or middle afternoon and continues at a steadily increasing tempo until dusk when it stops abruptly. The first birds to return are scattered individuals, or at most, groups of less than ten. These straggle in during most of the afternoon. Although the flocks in the late afternoon still are small, the number of returning birds increases because of the greater number of returning groups. An hour to an hour and a half before sunset the size of the returning flocks begins to increase until groups of fifteen or twenty are the rule. The number of returning flocks increases as they grow in size, until at sundown there is a steady stream of returning birds. Immediately after sunset the number, but not the size, of the returning flocks falls off sharply and fifteen minutes after the sun has disappeared, all the cormorants are home for the night.

One variation of this procedure occurred on December 21, 1940, which was a dark, windy, rainy day. Presumably because the weather was stormy, the cormorants returned steadily in small groups during the entire afternoon and then tapered off gradually so that all had settled on the roost by 4:45 p.m. without a concerted rush at sunset. During summer the days are so long that the cormorants have all returned to the power line some time before sunset and the concerted rush late in the afternoon is not as conspicuous as in winter.

The part of the power line on which the returning cormorants elect to perch determines their distribution on the roost and the way in which this choice shifts during the afternoon as the wires become filled throws some light on the gregarious nature of these birds. Between the east shore of the Bay and Brooks Island there are twelve towers. The birds group themselves on the wires in the immediate vicinity of the towers, but not as a rule in the areas midway between towers. Consequently their distribution along the line is discontinuous. The cormorants probably congregate near the towers because here the swaying of the wires under the influence of the wind is at a minimum.

About eight to ten per cent of the total number perch in the framework of the towers rather than on the wires. The number of birds roosting in the framework of any one tower rarely exceeds twenty although a tower could accommodate six or eight times that number. During the day the cement platforms on which the towers are built often have a few cormorants on them, but none spend the night there, although the platforms are high enough above the water not to be awash except during a high tide in a storm. Those parts of the power line on which the cormorants most frequently roost are readily discernible because of the white color given them by the coating of excrement.

The Double-crested Cormorants have a monopoly on this power line as a roosting site. Not once was any other kind of bird seen roosting on the wires even when there were no cormorants in the vicinity. On rare occasions, however, a gull will alight in the framework of one of the towers and quite frequently several gulls may be seen on the cement platforms beneath the towers.

The first cormorants to return to the power line in the afternoon always perch near one or another of the four towers which are farthest from land. These middle towers do not fill up simultaneously or at even approximately the same rate. One tower will acquire its full quota of 250 or 300 birds while the others remain deserted. Cormorants are gregarious and they continue to alight on one limited segment of the power line until it is so crowded that they are forced to perch near some other tower. As a result,

the wires around two or three towers will be completely filled while all the rest of the power line remains empty. As the tempo of return increases in the late afternoon, more and more towers begin to fill up simultaneously, but even so, the wires near one tower often remain completely deserted until just before sunset when the final rush begins.

It will be remembered that the birds leave the power line as individuals and form flocks only after they have flown some distance from the roost. The breaking up of the returning flocks is strictly comparable to the formation of the departing flocks, because the actual alighting, just like the actual taking-off is done by one bird at a time. A flock of twenty-five cormorants returning to the roost in an irregular "V" formation, thirty feet above the water, usually breaks ranks about seventy-five yards from the power line, and the individual birds scatter and come to roost, often along the whole length of the power line, but usually near three or four adjacent towers. Once the flock has broken up there is no hint of concerted action; each bird alights independently of the others. One bird may circle twice before attempting to land, another will fly directly to the nearest tower and perch without further ado, while a third may drop down close to the water and fly along beneath the wires for three-quarters of a mile before angling upward sharply and coming to roost.

In calm weather, a cormorant may approach the wires from either side, but always in such a manner that the long axis of its body is at right angles to the wires; this facilitates the grasping of the wire with the feet. When the wind is blowing more than five or six miles per hour, the birds head into it as they near the roost even though this necessitates swinging in a circle and coming in from a direction opposite from that of the initial approach. The power line runs east and west so that when the wind is parallel with the wires, in order to land heading into the wind, a cormorant must also be parallel with the wires as it flies in. This is obviously an awkward method of approach and frequently a cormorant landing in this manner cannot at first maintain its balance and has to flap its wings wildly until it has shifted its feet and obtained a firm grip on the wire. When the wind is blowing ten to twenty miles an hour, the birds seem to experience less difficulty in landing than when it is calm, because the wind stops their forward motion and they need do little if any back-paddling. Cormorants often miscalculate and miss the wire completely. They then drop down near the surface of the water, fly in a circle and try again. Individual birds sometimes make three attempts before successfully establishing themselves on the roost. More frequently, the cormorants misjudge the distance by only a few inches, come in too low and manage to grasp the wire with only one foot. They then have to flap their wings frantically until they can grasp the wire with the other foot and pull themselves up onto the wire and establish their balance.

In initially gaining its equilibrium on a wire, a cormorant raises and lowers its long tail and bobs its head up and down much like a robin on a swaying clothes line. Once it has established itself, it appears to have no difficulty in maintaining its position despite its totipalmate feet which seem poorly adapted for grasping anything as small as a high tension wire. The length of the digits in a cormorant's foot decreases progressively from the outermost to the innermost. The inside toe is less than a third as long as the outside one and is at least partially opposable. When a cormorant is perching on an object of small diameter, this digit grasps the perch from the rear while the other three grasp it from the front.

Despite the gregarious roosting habits of cormorants there are sometimes brief fights between birds that are already on the power line and those attempting to alight on it. These fights are largely formal and consist of threats and posturings rather than

actual bodily contact. Only one type of threat is used in fights over perches on the power line. The threatening bird turns its head in the direction of the newcomer, opens its bill and then thrusts its head directly out at the approaching bird. There may be one or several thrusts depending on the ease with which the newcomer is driven off.

Like most diving birds, a cormorant's legs are set far back on its body so that when standing it assumes a nearly erect position. When the wind is blowing less than ten

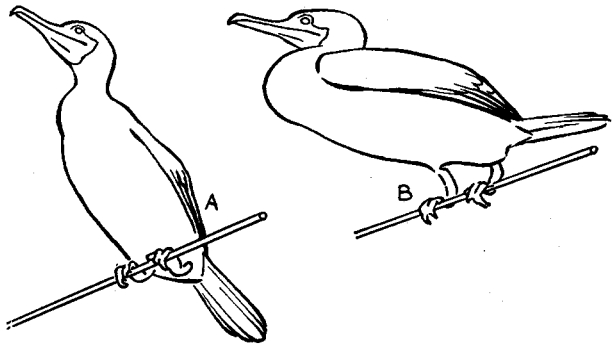

Fig. 2. Postures of roosting Double-crested Cormorants. A, normal position on power line; B, position assumed in a high wind.

miles per hour, a cormorant roosting on the power line assumes the normal posture (see fig. 2A) with the tail extending down below the wire, but when the wind blows in excess of fifteen miles per hour there is a marked alteration. The body is shifted forward until its longitudinal axis is nearly horizontal and the tail extends straight out behind. The neck is drawn in against the shoulders and the head is in the same horizontal plane as the rest of the body (see fig. 2B). This posture is obviously assumed because it decreases wind resistance. When in this horizontal position, balance is maintained largely by raising and lowering the tail.

On February 21, 1941, I spent the entire day watching the cormorants on the power line and on this particular day, according to the weather bureau, the wind at times was in excess of forty miles per hour. In spite of the violence of the wind, no cormorants were actually blown from the wires. Whole groups of birds, however, repeatedly left the wires after perching there for from fifteen minutes to an hour, apparently because the strain of balancing themselves on the power line was too great. On two occasions during the winter of 1941 the difficulty of maintaining their perch on the swaying wires during a sustained strong wind caused all the cormorants to leave the power line in the course of the night.

Heavy rains, if not accompanied by wind, have no effect on the departure of cormorants from the power line nor on their posture and method of roosting.

TIME OF DEPARTURE FROM THE NIGHTTIME ROOST

The time of departure from the power line, although variable, does not coincide as closely with the time of sunrise as one might expect. From September through February there appeared to be no direct relationship between the two, but in March, April, and May, as the days grew longer, the birds left progressively earlier. On June 27, however, the birds did not begin to leave until 6:00 a.m., fully an hour and forty minutes after it was light, and the last of them did not leave until 7:45. A possible cause for the

late departure of the birds during September and October was the fact that in these months they were fishing between the Berkeley Pier and the approach to the San Francisco-Oakland Bay Bridge and had only six or eight miles to fly to reach their feeding grounds.

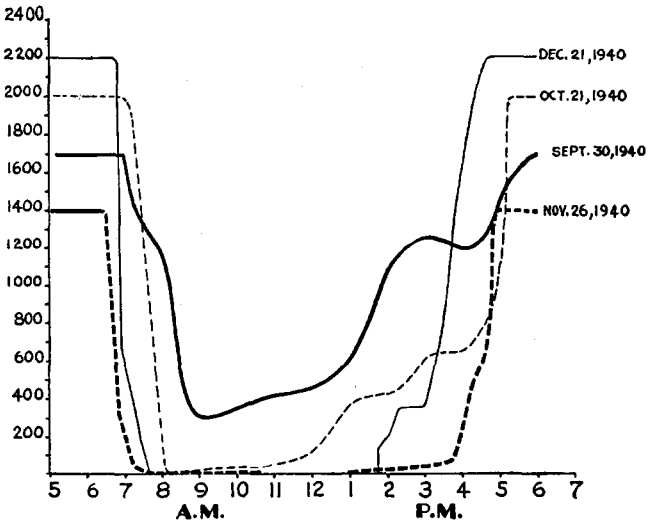

Fig. 3. Graph showing diurnal fluctuations in numbers of Double-crested Cormorants on Brooks Island power line. Fall and winter period.

On the whole, my data on the time of departure are inadequate to support satisfactorily any generalizations, although there appears to be a relationship of uncertain significance between the beginning of the departure of the birds from the power line and total number of birds roosting thereon. The cormorants tend to depart from the power line latest on those mornings when there are the most birds and earliest when there are the fewest birds.

TABLE 1

Departure from Power Line

	Beginning of departure	End of departure	Duration of departure	Number of birds on wires
Sept. 30	7:15	9:45	2:30	1700
Oct. 21	7:00	8:05	1:05	2000
Nov. 26	6:40	7:25	0:45	1400
Dec. 21	6:50	7:25	0:35	2200
Jan. 24	7:00	8:30	1:30	2400
Feb. 28	6:45	8:09	1:24	1900
Mar. 14	6:15	6:50	0:35	940
Apr. 11	5:30	5:40	0:10	470
May 26	4:55	5:30	0:35	650
June 27	6:00	7:45	1:45	900
July 29	6:50	9:00	2:10	1890

TIME OF RETURN

As the graphs (figs. 3, 4, 5) indicate, the return to the power line is a much more gradual process than the departure. During the day the birds are widely scattered over the Bay and each small group returns more or less independently of the others. The

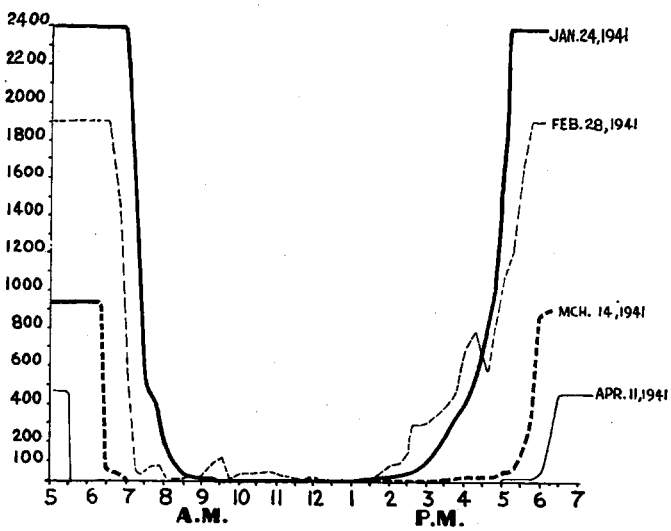

Fig. 4. Diurnal fluctuations in numbers of cormorants in winter and spring.

duration of the return is extremely variable. It is primarily dependent on the distance away from the home roost of the area that most of the birds have selected for their fishing. If the fishing area is near the power line, the first birds may return to the roost

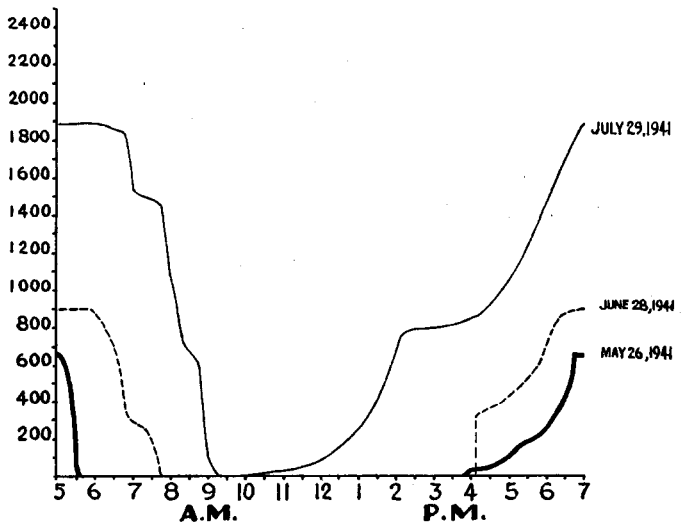

Fig. 5. Diurnal fluctuations in numbers of cormorants in spring and summer.

TABLE 2

Return to Power Line

	Beginning of return	End of return	Duration of return
Sept. 30	8:36 a.m.	6:00 p.m.	9:24
Oct. 21	10:31 a.m.	5:21 p.m.	6:50
Nov. 26	1:30 p.m.	5:05 p.m.	3:35
Dec. 21	1:45 p.m.	4:45 p.m.	3:00
Jan. 24	2:00 p.m.	5:12 p.m.	3:12
*Feb. 28	7:50 a.m.	5:45 p.m.	9:55
Mar. 14	4:25 p.m.	6:17 p.m.	1:52
Apr. 11	5:01 p.m.	6:30 p.m.	1:29
May 26	3:30 p.m.	6:45 p.m.	3:15
June 27	3:00 p.m.	6:30 p.m.	3:30
July 29	12:00 p.m.	6:30 p.m.	6:30

*A violently windy day on which almost all the birds remained in the vicinity of the power line.

TABLE 3

Number of Double-crested Cormorants occurring in the Berkeley Aquatic Park, from April, 1940, through March, 1941. Dash indicates no observation.

	Day of month																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
April	3	2	0	0	0	1	4	2	4	3	3	1	1	2	3	2	3	2	3	2	2	3	2	2	4	2	1	1	1	4	
May	1	3	0	3	0	1	1	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	2	1	0	1	1	0	1	0
June	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	2	1	1	0	1	2	1	0	
July	0	0	0	1	1	1	1	1	1	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	2	0	1	0	3	3
September	2	1	0	3	5	2	0	5	4	7	5	4	5	6	6	4	9	2	11	0	3	2	2	11	9	2	13	9	12	4	
October	10	20	14	14	14	0	8	7	4	0	6	4	3	5	4	8	2	1	6	20	8	16	24	42	21	42	3	55	80	61	87
November	41	59	46	57	147	140	306	210	115	42	35	1	153	169	172	17	121	4	103	156	36	48	142	35	40	152	73	38	70	36	
December	16	5	12	15	10	11	24	24	2	14	6	29	16	30	27	18	19	13	12	11	19	23	15	21	19	22	14	14	13	15	13
January	14	2	6	7	13	23	22	22	14	13	6	10	10	13	8	6	5	13	17	0	0	0	0	0	0	0	0	0	0	0	0
February	6	9	6	17	4	2	3	0	3	5	1	1	3	0	1	1	0	0	2	0	2	1	2	—	—	—	—	—			
March	—	1	—	—	—	0	0	1	0	0	0	4	2	1	2	4	2	2	1	2	209	175	—	331	4	7	5	9	10	76	11

in the middle of the morning, but if the fishing area is some miles distant, the chances are that the birds will not return to the power line until shortly before sunset.

On September 30, 1940, the departure and the return were going on simultaneously, for in the middle of the morning when the first birds began to return to the power line, more than 250 of the cormorants which had spent the night there still remained.

September 30 and October 21, 1940, were the only two days on which the return to the power line began early in the morning and in the late afternoon of both these days there was an actual decrease in the number of birds on the roost despite the fact that all the while there was a steady stream of birds returning to the power line. The diminution was caused by the departure of several hundred birds which, since they had returned in the middle of the morning, had been roosting almost five hours. They apparently left the wires because they were hungry. At any rate, they formed a large active fishing flock beneath the power line. On February 28, some birds returned to perch on the wires in the morning, but these had never left the vicinity of the power line because of the violent wind.

The termination of the return to the power line seems to be closely related to the time of sunset. In the winter the return ended relatively early in the day and during the late spring and summer, relatively late in the day. The difference between the earliest and latest terminations of return is two hours, whereas the difference between the times of sunset on the longest and the shortest days of the year at the latitude of San Francisco Bay is approximately 2 hours and 40 minutes.

DAYTIME ROOSTING

A cormorant does not fish continuously throughout the day. Periods of fishing alternate with much longer periods of rest, during which the birds perch out of the water. So pronounced is the tendency to spend most of the day roosting that the availability of roosting sites is the most important factor in determining whether or not a particular part of the Bay will contain cormorants. The number of suitable roosting sites in the part of the Bay in which I observed is limited and those sites which fill the necessary requirements usually support cormorants.

The requisites for an adequate roosting site are definite. It must be so situated that it is not often disturbed by man. It must be either on the edge of, or surrounded by, water. There must be an adequate supply of fish so that the cormorants can obtain food in the immediate vicinity of the roost and the roost must be barren of vegetation or must offer unobstructed visibility. These requirements apply only to those roosts on which sizeable groups of cormorants habitually spend their time when they are away from the Brooks Island power line. Individual cormorants can be found on occasion in nearly any undisturbed spot on the Bay where there is room for one to perch. The following list includes all the daytime roosting sites commonly used by Double-crested Cormorants in the east-central part of San Francisco Bay (see fig. 1):

1. Castro Rocks, west of Point Richmond
2. The breakwater on the south side of the Richmond Channel
3. The east end of the breakwater on the north side of the Berkeley Yacht Harbor
4. The pilings west of the Berkeley Yacht Harbor
5. The log boom north of the bird island in the Berkeley Aquatic Park
6. The barren sand bar northwest of the toll station on the San Francisco-Oakland Bay Bridge
7. The abandoned ferry slip at the west end of the Berkeley Pier

It was impossible for me to keep a daily record of the number of cormorants occurring at any one roosting site, but I was fortunate in being given a record of the number occurring in the Berkeley Aquatic Park for virtually every day of the year. This record was made by David G. Nichols and Monique Nichols who obtained it incidental to

making a daily census of the birds occurring in the Aquatic Park from April 1, 1940, to April 1, 1941; they have very kindly allowed the inclusion of their findings in this paper. With few exceptions, all counts were made in the early morning and include only those birds actually roosting or fishing and not those merely flying over.

Table 3 indicates the seasonal fluctuations in the number of cormorants at the Aquatic Park. The dearth of birds in April, May, June, and July is an expression of the reduced number of birds present on the Bay as a whole, for in the spring and summer many cormorants move to the breeding colonies on the coast (see fig. 6 for seasonal fluctuations in numbers of Double-crested Cormorants on central San Francisco Bay). The large number recorded in October, November, and December, although indirectly due to the abundance of the birds on the Bay in these months, is primarily the result of the fact that in this period almost all the cormorants on the central part

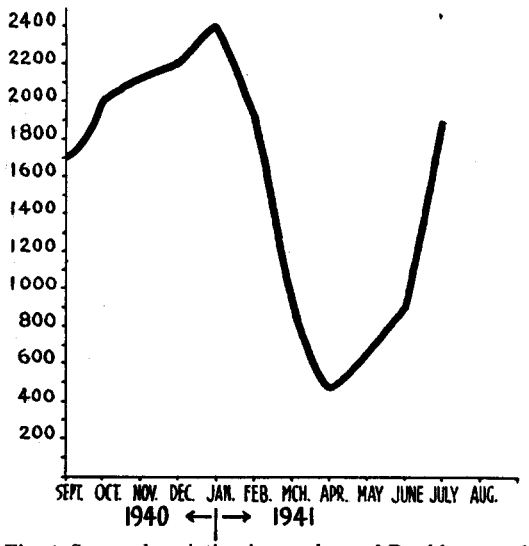

Fig. 6. Seasonal variation in numbers of Double-crested Cormorants spending nights on Brooks Island power line.

of the Bay were fishing in an area just west of the Aquatic Park. Although in February and the first part of March the cormorants on the Bay as a whole were as abundant as in the fall, only a few were seen at the Aquatic Park because nearly all of them were fishing on the west side of the Bay in the vicinity of Angel Island, far away from Berkeley.

The seasonal shift in the fishing areas of the cormorants is the principal factor in determining the number of birds to be found on the various daytime roosting sites. Each site has its largest quota of birds during the part of the year in which the main fishing area of the cormorants is in its vicinity, and the smallest quota when the birds are fishing in some other part of the Bay. In the fall of 1940, the Double-crested Cormorants on the central part of San Francisco Bay were fishing in the area between the Bay Bridge approach and the Berkeley Pier. During the winter, they spent their days on the west side of the Bay north of the Golden Gate in the vicinity of Sausalito, Tiburon, and Angel Island. In the spring most of them were fishing south and east of the San Francisco-Oakland Bay Bridge, some even on the south side of Alameda. In the early summer they shifted back to the area around Angel Island.

When the cormorants were fishing in the part of the Bay near the Berkeley Aquatic Park (November), or passing over it on the way to their fishing grounds (March), as many as 200 or even 300 of them were sometimes seen on the lagoon in the early morning. Such large flocks, however, seldom remained for more than half an hour, because the Aquatic Park is too small to furnish enough fish to maintain so many birds throughout the day. These big groups would alight on the lagoon, fish for perhaps thirty minutes and then apparently because of the poor fishing, would leave. Only a few, always less than forty and usually less than ten, would remain to spend the day.

On the log boom in the Aquatic Park, and on all the other daytime roosts, there are as a rule more cormorants in the morning than in the afternoon, because as the day wears on the birds tend to return to the Brooks Island power line.

From this discussion it is apparent that the number of cormorants occurring on the various daytime roosting sites is dependent on three factors. Listed in the order of their importance they are: the part of the Bay in which the birds are fishing, the total number of birds on the Bay, and the time of day.

The tendency of cormorants to remain in the water only as long as they are fishing is undoubtedly associated with the structure of their feathers, for surprisingly enough, despite the fact that the bodily form of a cormorant is nicely adapted for aquatic life, the feathers are readily penetrated by water. As Lewis (1929:60) has pointed out, "if they remain long immersed they become very wet and bedraggled, the contour feathers clinging together in tufts, like wet hair, and exposing the light gray down underneath." This susceptibility to wetting is the result, not of a lack of oil, but of the loose and open structure of the feathers.

With plumage so readily penetrated by water, it is to be expected that cormorants would not spend all their time on the water as the grebes and many of the ducks on the Bay do in the winter. So strong is this tendency to remain out of the water when not actually fishing, that only once have I seen a group of cormorants resting on the water and then it was probably due to the fact that the roosting site which they would ordinarily have used was so crowded that it would have been difficult to find a place to perch.

RELATIONS BETWEEN BRANDT AND DOUBLE-CRESTED CORMORANTS

In the area of study, Brandt and Double-crested Cormorants regularly come in contact at only one place, Castro Rocks west of Point Richmond, for the Brandt Cormorants are rarely seen east of the outer end of the breakwater marking the south side of the Richmond Channel.

The Castro Rocks are the home roost of the Brandt Cormorants, and all these birds in the area of study return here every night; at least a few roost here at all hours of the day. The largest number of Brandt Cormorants seen at any one time was ninety, but no attempt was made to keep a record of seasonal population changes.

Unlike the Brandt Cormorants, the Double-crested Cormorants use the Castro Rocks only as a daytime roosting site. Consequently, the daily cycles of the two species at this common roost are different (see fig. 7). The cycle for the Brandt Cormorants at Castro Rocks is essentially the same as that of the Double-crested Cormorants on the Brooks Island power line. They depart in the early morning and during the rest of the morning and the early afternoon only a few birds are in the vicinity. In the middle of the afternoon the birds begin to return and the return continues all afternoon until at sunset all are back. Since the number of Brandts is small, these movements involve no large flocks.

The daily cycle of the Double-crested Cormorants on Castro Rocks is exactly the reverse of that of the Brandts. There are no birds of the former species at the roost in the early morning because none spend the night there. During the morning scattered

individuals and groups of two or three fly in and alight on the roost. The number of birds reaches its maximum in the middle of the afternoon and then begins to fall as the birds return to the Brooks Island power line to spend the night.

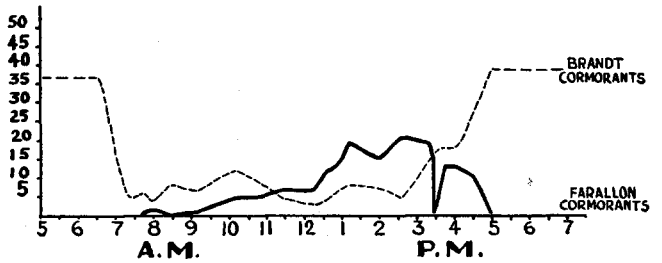

Fig. 7. Graph indicating number of Brandt and Double-crested (Farallon) Cormorants present on Castro Rocks during the day of February 21, 1941.

The irregularities in the numbers of cormorants on the rocks, from one-half hour to the next, result from the fact that off and on during the day groups of both species leave the roost to fish. The Double-crested Cormorants almost always fish in the immediate vicinity of the rocks, but the Brandt Cormorants rarely do; they usually fly to some other part of the Bay.

Although there is no antagonism between the two species of cormorants on the rocks, they tend to remain aloof. This is especially noticeable when there are not many birds present, but the tendency appears to exist at all times. In the month of February, 1941, when most of the observations at this roost were made, the Brandts always roosted on the two southern rocks, while the Double-crested Cormorants perched on the northern rock. The two species sometimes perched side by side on some of the small low-lying rocks.

At 5:05 p.m. on February 21, 1941, when all but three of the Double-crested Cormorants had returned to the Brooks Island power line, an incident occurred which illustrates the tendency of the birds of one species to remain together. Two of the three Double-crested Cormorants were perching side by side on one of the small low rocks which rise only a foot or so above the water at low tide and the third was fishing about seventy feet away. Between the fishing bird and the other two members of its species was a line of almost submerged rocks on which approximately twenty Brandt Cormorants were perching. The lone Double-crested Cormorant, apparently looking for a place to perch, swam slowly along the line of rocks, paused once or twice but did not climb out of the water until it came to the two other members of its species whom it joined and all three perched side by side.

Michael (1935:36) in discussing the Brandt and Double-crested Cormorants which nest on the cliffs above the caves at La Jolla, California, says, "While all the cormorants perched on the same cliff, the birds of the two species did not mingle indiscriminately: the Farallons [Double-crests] occupied the uppermost tiers of perches exclusively while the Brandts kept to the ledges below the uppermost tiers. Each species recognized the rights of the others and there was never any apparent dispute between species."

Although at Castro Rocks the two species remain separate, their spatial relationship is just exactly the reverse of that at La Jolla. The Brandts tend to roost on the top of the rocks while the Double-crests tend to roost at the water's edge. This distribution, however, is not so much an indication of preference as it is the following of the path of least resistance. The Brandts almost always approach the rocks on the wing since they fish in

other parts of the Bay and the easiest place for them to land is on the tops of the rocks. The Double-crested Cormorants fish in the water near the rocks and when they get ready to roost they swim up and climb onto the rocks from the water, perching near its edge.

SUMMARY

The roosting activities and daily movements of Double-crested and Brandt Cormorants on San Francisco Bay were studied for a period of eleven months. The Brandt Cormorants have their home roost on the Castro Rocks and confine their activities to the middle and western parts of the Bay. The Double-crested Cormorants, which during the day scatter widely over the entire central part of the Bay, return every night to roost on the Brooks Island power line. No record was kept of seasonal shifts in the population of Brandt Cormorants. The maximum number (2300) of Double-crested Cormorants was present in January and the minimum number (470) in April. The time of departure of the Double-crested Cormorants from their nighttime roost in the morning was more nearly related to the total number of birds roosting thereon than to the time of sunrise; the smaller the number of birds, the earlier the departure. The time of the beginning of the return to the nighttime roost depended on the number of birds present and on the part of the Bay in which they were fishing; the greater the number of birds and the closer to the roost they fished, the earlier in the day they began to return.

The usual method of departure of the birds from the nighttime roost was to leave individually or in small groups. Flocks formed after the birds had flown a quarter of a mile or more from the roost. The flocks assumed a single line or an asymmetrical "V" formation and their speed varied between twenty-four and twenty-eight miles per hour.

Because of the ease with which their feathers are penetrated by water, cormorants remain in the water only while they are actually fishing; in the area of study the birds perched on seven daytime roosting sites.

Strong winds cause roosting cormorants to alter their positions so as to reduce wind resistance. Sustained strong wind, although it never actually blew the cormorants off from their roost on the power line, sometimes made them so uncomfortable that they were forced to depart.

The part of the Bay in which most of the Double-crested Cormorants fished varied from month to month and determined the number of birds to be found on the various daytime roosts at any season.

Brandt and Double-crested Cormorants associated regularly only on the Castro Rocks, a daytime roost for Double-crests and the home roost for the Brandts. There was no apparent friction between the two species, but each tended to remain aloof from the other.

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