

FINAL REPORT

POINT REYES NATIONAL SEASHORE
POINT REYES CALIFORNIA 94956

Avifaunal Surveys of the Limantour Estero Area

Point Reyes National Seashore

by

Point Reyes Bird Observatory

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INTRODUCTION

In July 1965 the Point Reyes Bird Observatory, under contract to the National Park Service, began a study of the birds of Limantour Estero in Drake's Bay. The purpose of the study was to assess the importance of this area to birds in the light of a master plan proposal incorporated in USNPS Drawing NS-PR 3025A, under which a substantial part of the estero was to be impounded by a spill dam and developed for boating and swimming.

The study was based on a regular detailed ground census. The estero and adjoining freshwater ponds were divided into twelve areas according to location, substrate type and vegetation, and the number of each species was recorded systematically for every area. In this way it was possible to acquire detailed knowledge of the value of different types of habitat and their interrelation at various seasons of the year and at different stages of the tide.

Since April 1968 the study has received additional support from the California Fish and Game Department Special Wildlife Investigations Project (Pittman-Robertson W54R1). This support has consisted chiefly of an aerial census made cooperatively by Fish and Game and Bird Observatory investigators, and a photographic flight which produced the mosaic on which the acreages quoted in this report are based.

The substantial data output from the study has been card-punched for computer analysis by the Marine Resources Operations branch of the California Department of Fish and Game and a program has been devised by the National Forest Service. Analysis of these data will provide a basis for recommendations to agencies concerned with management and conservation of wetland habitat.

Although the National Park Service grant to the Bird Observatory expired on June 30, 1969, this report must not be construed as representing the conclusion of the study. Censuses, both from the ground and from the air, are continuing as before and, of course, the analysis of data is still in a very early stage with immense scope for expansion. No comparable study has amassed so much data over such a long period.

FIG. 1. MAP OF CENSUS AREAS AT LIMANTOUR ESTERO

Approximate Scale: 1 inch = $\frac{1}{2}$ mile

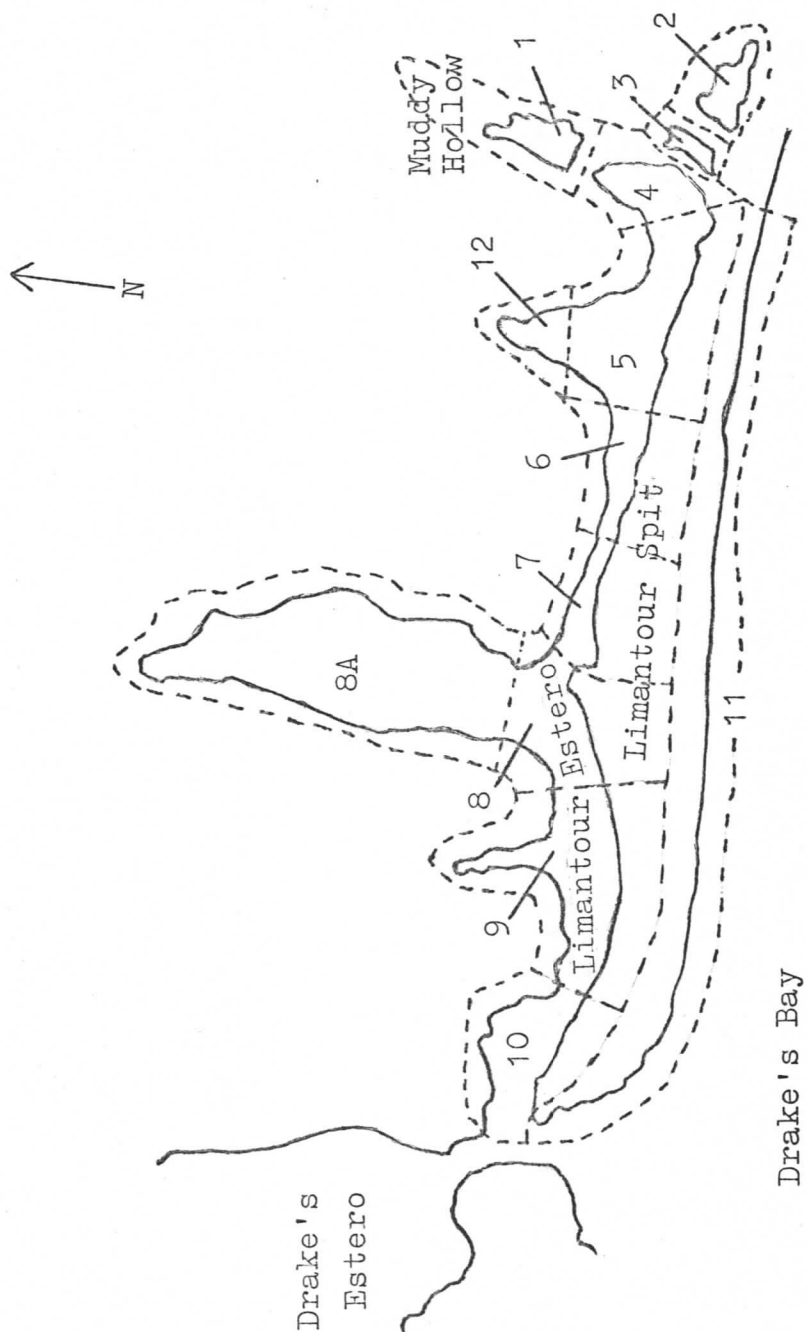


Table 1. Census Areas at Limantour Estero.

Area No.	Total Acres	Description and Location	Birds Using Area	Resources and Habitat Evaluation
1	12	Muddy Hollow Pond: dammed freshwater pond.	Coot, dabbling ducks, Pied-billed Grebe.	Abundant bottom vegetation. Good surface-feeder habitat. <u>Good pond habitat.</u>
2	5	Freshwater pond east of paved access road.	Coot, Mallard, teal, herons, some shorebirds (esp. Long-billed Dowitchers), Common Snipe, American Bittern.	Thick vegetation. Rich substrate mud usually covered by water. Coot, Mallard, Pied-billed Grebe breed. <u>Good pond habitat.</u>
3	2	Outflow channel from area 2 and surrounding marsh.	Ducks (usually dabbling), coot, shorebirds.	Little marsh or mud. <u>Not a productive area.</u>
4	34	Elevated mudflat surrounded by salt marsh. East end of main channel.	Shorebirds (all kinds), ducks (all), coot, gulls.	Rich soft mud substrate. Mudflat (15 acres) nearly always exposed. Important feeding area especially at higher tides. Marsh (12 acres) much used for feeding and resting. <u>One of most important areas.</u>
5	55	Shallow basin just west of area 4 with mudflat and salt marsh.	Shorebirds, herons, ducks (all), coot, gulls.	Substrate is richest of any area. Highest preference for shorebird feeding. Much used by surface-feeding and diving waterfowl, herons, egrets, and gulls. Marsh (8 acres) an important feeding, resting and night roosting area. <u>One of most important areas.</u>
6	29	Main channel west of area 5, with sandy flat and marsh.	Diving ducks, shorebirds, herons, coot, gulls.	Intertidal flat good shorebird feeding and gull resting area. Marsh (5 acres) used for feeding. Deeper main channel much used by diving ducks. <u>More limited than area 5.</u>

Area No.	Total Acres	Description and Location	Birds Using Area	Resources and Habitat Evaluation
7	38	Deep narrow main channel to east of bay mouth backed by extensive sand flat.	Shorebirds, diving ducks, grebes.	<u>Elgrass bed (5 acres) valuable for diving ducks and brant. Sand flats used for resting at high tide. Limited but useful habitat.</u>
8	73	Wide, mostly shallow basin at mouth of bay with gently sloping sand flats.	Diving ducks, Black Brant, shorebirds, gulls, herons, coots, grebes.	<u>Elgrass (10 acres)--best area (with 8A) for Black Brant and diving ducks. Sand flats major resting area for waterfowl, gulls and shorebirds. Varied important habitat.</u>
8A	204	Wide bay to north of estero. Limited surrounding flats.	Black Brant, diving ducks, gulls, cormorants, shorebirds.	<u>Largest area of eelgrass (47 acres) invaluable for Black Brant. One of estero's vital resources. Good feeding area for bottom-feeders (diving ducks, cormorants). Critically important area.</u>
9	75	Wide main channel to west of bay mouth (area 8). Wide sandy flats back to dunes.	Diving ducks, shorebirds, gulls, grebes, cormorants, loons, pelicans.	<u>Elgrass (11 acres) in main channel. Sandflats used by feeding shorebirds. Dry sand important resting area. Less varied than area 8 but important.</u>
10	63	Estero mouth and adjoining sand flats.	Diving ducks, shorebirds, gulls, loons, herons, cormorants, pelicans.	<u>Fast-flowing deeper water much used by diving species. Flats exposed at low tide used by shorebirds. Good but specialized habitat.</u>
11	75*	Ocean beach back to dunes.	Sanderling, Willet, diving ducks, gulls.	<u>Dune area used for resting. Main beach of limited value. Limited usefulness.</u>
590* TOTAL				

*Approximately 75 acres of ocean beach normally censused are not included in total acreage.

METHODS

The Study Area

Limantour Estero shares a common mouth with Drake's Estero on the north shore of Drake's Bay about 25 miles northwest of San Francisco. The main arm of the estero extends two and a half miles due east from the mouth, and one large bay (area 8A) nearly $1\frac{1}{4}$ miles long and 2000 feet wide adjoins the main channel to the north. At the east end there are two inlets to the north, both of which have been dammed in recent times, one in 1952-53, the other in the early 1960's. The estero is bounded to the south by a sandspit with intermittent patches of sparse dune grass at its western end (i.e., toward the mouth) and denser vegetation at the east end, consisting of marsh weed, coarse grass and low scrub. On the south bank there are large expanses of intertidal flat (areas 5-10) of varying sandy composition while at the west end there is a softer mudflat. The north bank slopes down to the water's edge, often quite steeply--at the east end from rough pasture land overgrown with scrub, and at the west end from cliffs up to two hundred feet.

There is an extensive underwater vegetation consisting mainly of eelgrass (Zostera marina).

The ground censuses since the 1966-67 season have incorporated a division of the estero into habitat types (Fig. 1). These are described in Table 1 with acreages based on analysis of a mosaic of aerial photographs of Limantour taken on July 3, 1969, by the California Department of Fish and Game.

Ground Census

The accumulation of regular and detailed census data from four seasons of field work has been a unique feature of this study. All birds depending upon or influencing the estero were included in the census: loons, grebes, pelicans and cormorants, herons and egrets, all ducks, geese and swans, rails and coot, all shorebirds, gulls, terns, and alcids. Census observations were broken down by areas as described in Table 1, and within each area, by general habitat type; e.g., water or marsh. The time taken to make a census varied from about two to seven hours. Censuses were made by salaried Observatory biologists--chiefly Philip Lenna (1966-67) and John Smail (1968-69). The analysis of data from these censuses is described in a later section of this report.

Aerial Census

The program of aerial censuses was carried out in cooperation with the California Department of Fish and Game. A four-seat Cessna Skylane aircraft was used with an observer on each

side dictating his counts into a tape recorder. The plane was flown about one hundred feet above the area at the slowest speed compatible with safety. Separation of species cannot be finely made in some groups but most species are readily distinguishable.

Flights were made from Marin County Airport in Novato and covered Tomales Bay, Abbott's Lagoon, Drake's Estero and Bolinas Lagoon, as well as Limantour Estero.

Banding

Nearly 1000 shorebirds of nine species have been banded and color marked in an effort to document shorebird movement--how long individual birds stay in the estero, whether they return in successive years, where they move in the estero, and where they travel throughout the state. Banding also enabled us to gather data on shorebird molt, body measurements, and age distribution.

All birds were captured in mist nets set up on the marsh in area 5, and marked on the breast with dye to make them conspicuous in the field. The nets were set up in the afternoon, tended throughout the night, and taken down on the following day. The captures during the 1968-69 season are shown later in this report.

Particle Size Analysis

In order to assess the consistency of the substrate in various areas in the estero a comparative analysis of particle sizes was made. Samples were taken at approximate hundred-yard intervals along the estero from the north end of area 4 to the tip of the spit in area 10. The data show that the flats in areas 6, 7, 8, 9, and 10 consist of a mixture of medium and fine sand, but that area 4 has, in addition, many larger and many finer particles which make the texture muddy. Area 5 has an intermediate composition especially where it joins area 4. There was a small amount of silt in some samples from areas 8 and 10 in places opposite freshwater streams. The raised flats in area 7, which are flooded only at tide levels over about 5.5 feet, are high in granules (particles that will not pass through a 2 mm sieve) and coarse sand.

LIMANTOUR ESTERO CENSUS

JULY 1968 THROUGH JUNE 1969

Table 2. Monthly Average of Individuals

SPECIES	1968 JUL	AUG	SEP	OCT	NOV	DEC	1969 JAN	FEB	MAR	APR	MAY	JUN	HIGH COUNT
Loon, Common		4	3	3	3	1	1	1	2	8	4	1	13
Yellow-billed Arctic	2	1			1	4					*		1
Red-throated Species ?	1	*	*	*	1	1		1	1	3	1		4
						2		1			2		3
								1					4
Grebe, Red-necked				1	1		2	1					2
Horned				*	4	9	11	17	15	26	2		36
Eared				2	1	4	7	7	15	1			28
Western			1	2	3	9	1	2	4	1			9
Pied-billed Species ?	5	6	9	9	8	3	4	1	1	2	2	1	13
								2					2
Pelican, White Brown	8	10	1	64 18	5 4	13							105 49
Gormorant, Dbl.-cr. Brandt's	1	14	19	17	10	14	9	1	4	18			36
Pelagic Species ?	10	27	28	1	*	4		*	1	1	2		5
						1			*	2	4		4
Great Blue Heron	6	5	1	3	4	3		2	4	9	2	10	11
Egret, Common	3	7	1	1	*		1	1	9	11	5	5	20
Snowy			2	1	*			2	1	1		1	5
American Bittern		1	1	1									3
Emperor Goose						2	2	30	630	761	375		2
Black Brant						8							1583
Mallard	6	6	2	59	1		4	1	2	4		12	110
Gadwall				2		4		8	2				17
Pintail		9	27	28	30	119	75						119
Teal, Green-winged				5	3				*				7
Cinnamon		2	2									1	5
Species ?													337
American Widgeon			95	133	143	307	113	93	206				25
Shoveler					9		3						17
Ring-necked Duck				5	10		3						17
Canvasback					1		7	1					7

SPECIES	1968 JUL	AUG	SEP	OCT	NOV	DEC	1969 JAN	FEB	MAR	APR	MAY	JUN	HIGH COUNT
Scaup, Greater					11		14	7	3	10			20
Lesser				5		103	35		7	17	6		34
Species ?					3	16	14	4	29	34	11		107
Common Goldeneye					161	471	187	83	65	1	4		16
Bufflehead								1	1	26			471
Oldsquaw				26	89	106	85	34	56	71	57	5	2
Scoter, Wh.-winged	3	1	12	25	58	142	35	35	91	93	22	34	130
Surf	9	5	10	*	*	2	70	1	2	5	6		146
Common				19	20	75			14	32	3	1	75
Species ?		11	2	1	48	422	297	163	14	10	2	1	422
Ruddy Duck	1				3	6	5	3	5	8	8	1	12
Merganser, Red-br.					167	100	700	100	200	93	25		700
Waterfowl species													
Osprey		*			1								1
Sora						1							1
American Coot	14	19	71	333	489	985	447	127	343	222	19	8	985
Plover, Semipal.	12	16	6	8	18	7	9	6	9	6	10	9	24
Snowy	1		13	16	63	10	22	44	24	11	1	3	116
Amer. Golden			1	1		1							1
Blk.-bellied	12	28	26	30	18	19	53	15	1	11	6		53
Killdeer	2		10	2							1	1	14
Turnstone, Ruddy	1												1
Black	2		14	34	8	4	15	2	8	4	6		45
Common Snipe				1	2								3
Curlew, Long-billed		5	1	2	1	1	1			1	1		7
Whimbrel	7	3	1		*					1			13
Spotted Sandpiper				1									1
Wandering Tattler				119	76	212	85	115	105	30	3		212
Willet	11	100	97	2	*	1	1	1	1	1	1		6
Greater Yellowlegs		1	6	105	222	900		234	875	173			1487
Peep		209	250	170	136	50	175	95	31	32	3		274
Sandpiper, Least	15	21	64	592	365	1270	628	475	421	494	255		1270
Western	348	394	239	565	945	1042	2180	368	296	146	15		2180
Dunlin			10										

SPECIES	1968 JUL	AUG	SEP	OCT	NOV	DEC	1969 JAN	FEB	MAR	APR	MAY	JUN	HIGH COUNT
Dowitcher, Sht.-bld.		18	4						*	10	*		30
Long-billed Species ?			26	1									51
Godwit, Marbled	1	14	11	7						3			6
Sanderling	13	267	285	16	8	6	15	3		1			30
American Avocet				111	183	143	86	65	160	47	66		392
Northern Phalarope	1	2	2	1									1
Baird's Sandpiper	1	1											3
													2
Gull, Glaucous-wgd.													
Western	166	142	147	1	2	44	3	2	30	4	2		85
Herring				81	125	30	22	22	23	23	7	3	224
Thayer's				2	5	28	8	2	40				72
California	1	4	57	1	1	1	1	2	2				2
Ring-billed	58	93	90	100	228	93	444	9	12	1	9	1	444
Mew	7	6		62	32	4	158	14	10	2	8		158
Bonaparte's					1	6	852	171	67				852
Heermann's	3	30	41	37	17					2	26	1	49
Species ?	59	94	5	135	207	50	50	121	68	29	29		89
Tern, Forster's	6			3						17			271
Common			1										34
Caspian	5	1										2	1
Elegant				10						23	11		25
Common Murre													20
													1

* Denotes that species was seen during the month but averaged below one per census.

Loon Species ? - predominantly Common or Arctic.
 Cormorant Species ? - probably almost all Double-crested.
 Grebe Species ? - Horned or Eared.
 Scoter Species ? - White-winged or Surf--predominantly Surf.
 Waterfowl Species ? - Includes loons, grebes, cormorants and coot as well as ducks. These birds were mostly in the upper end of the north arm of the estero.
 "Peep" - Least Sandpiper, Dunlin, Western Sandpiper.
 Gull Species ? - Predominantly California, Ring-billed (in mid-winter), and Mew with varying numbers of Western Gull.

FIG. 2. MONTHLY ABUNDANCE OF DUCKS

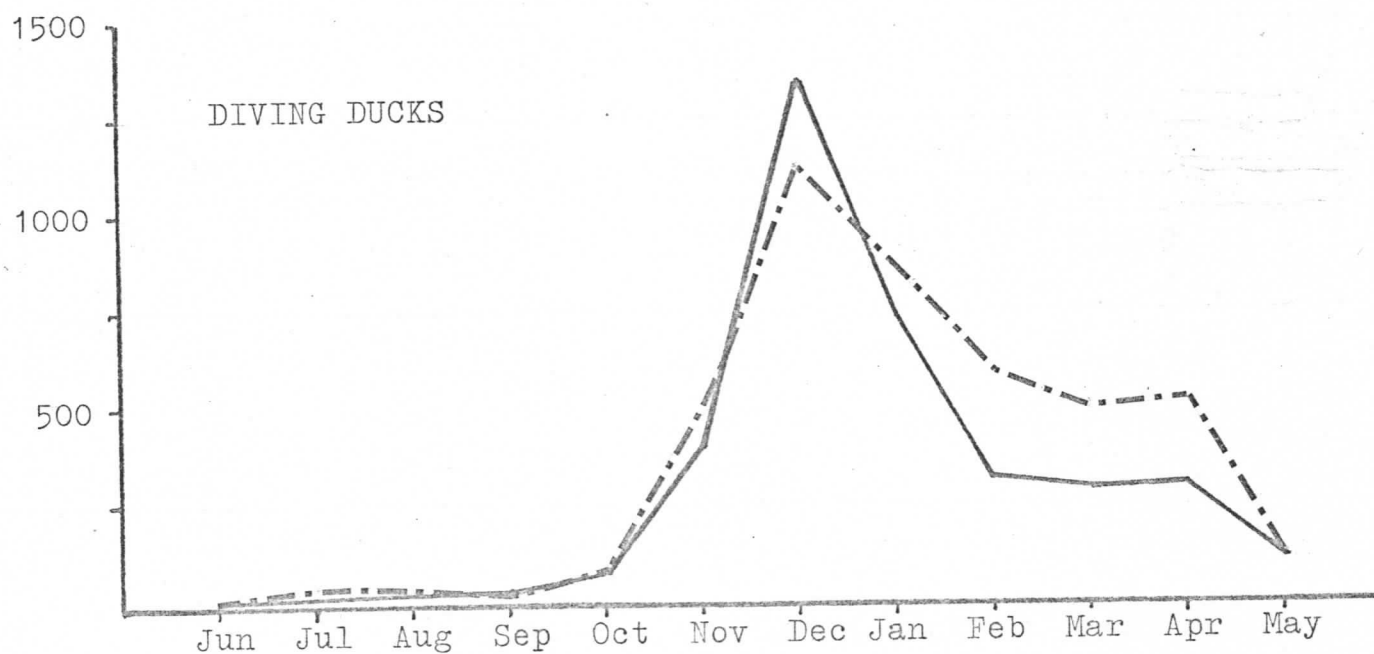
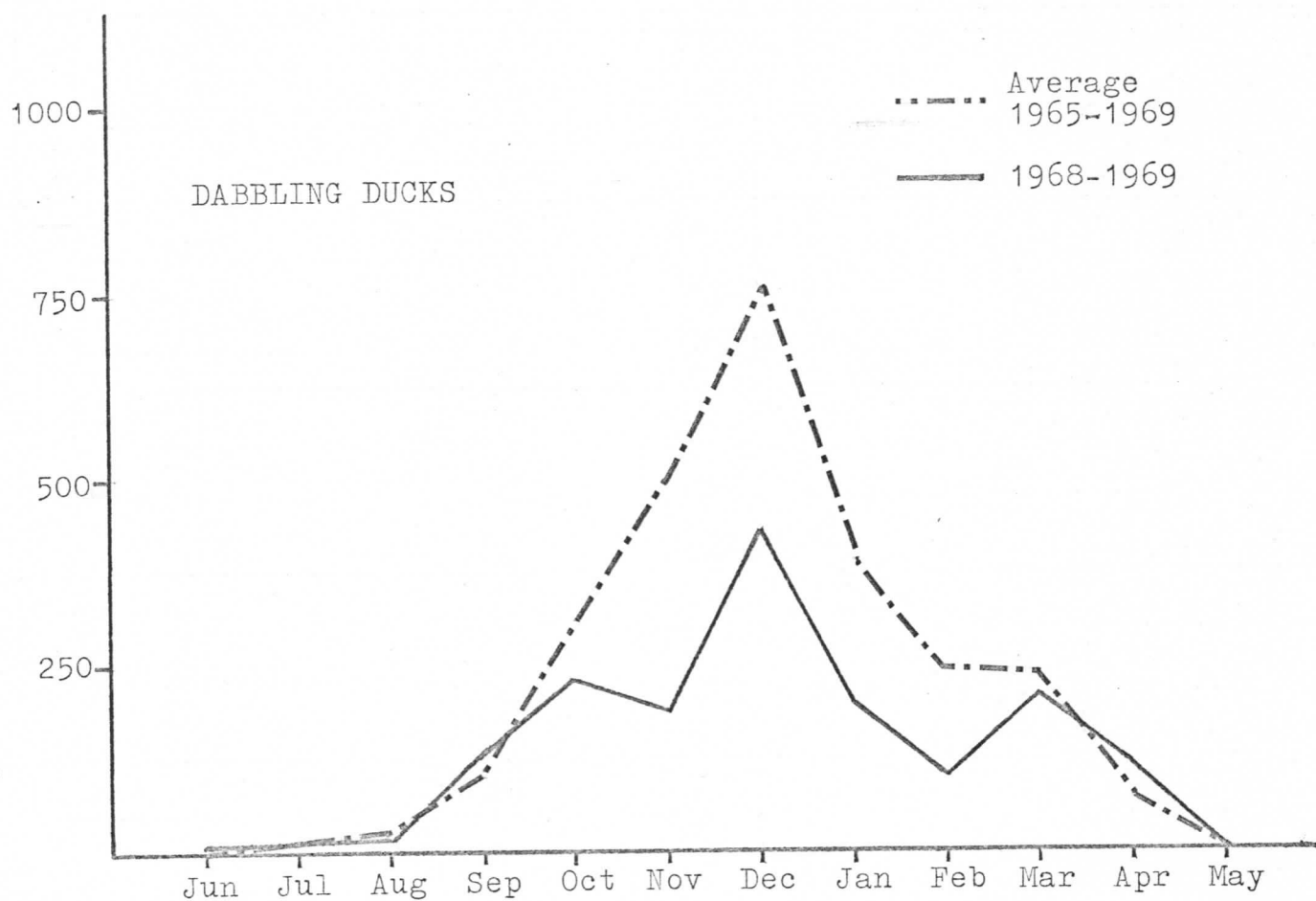


FIG. 3. MONTHLY ABUNDANCE OF BROWN PELICANS, BLACK BRANT, AND COOT

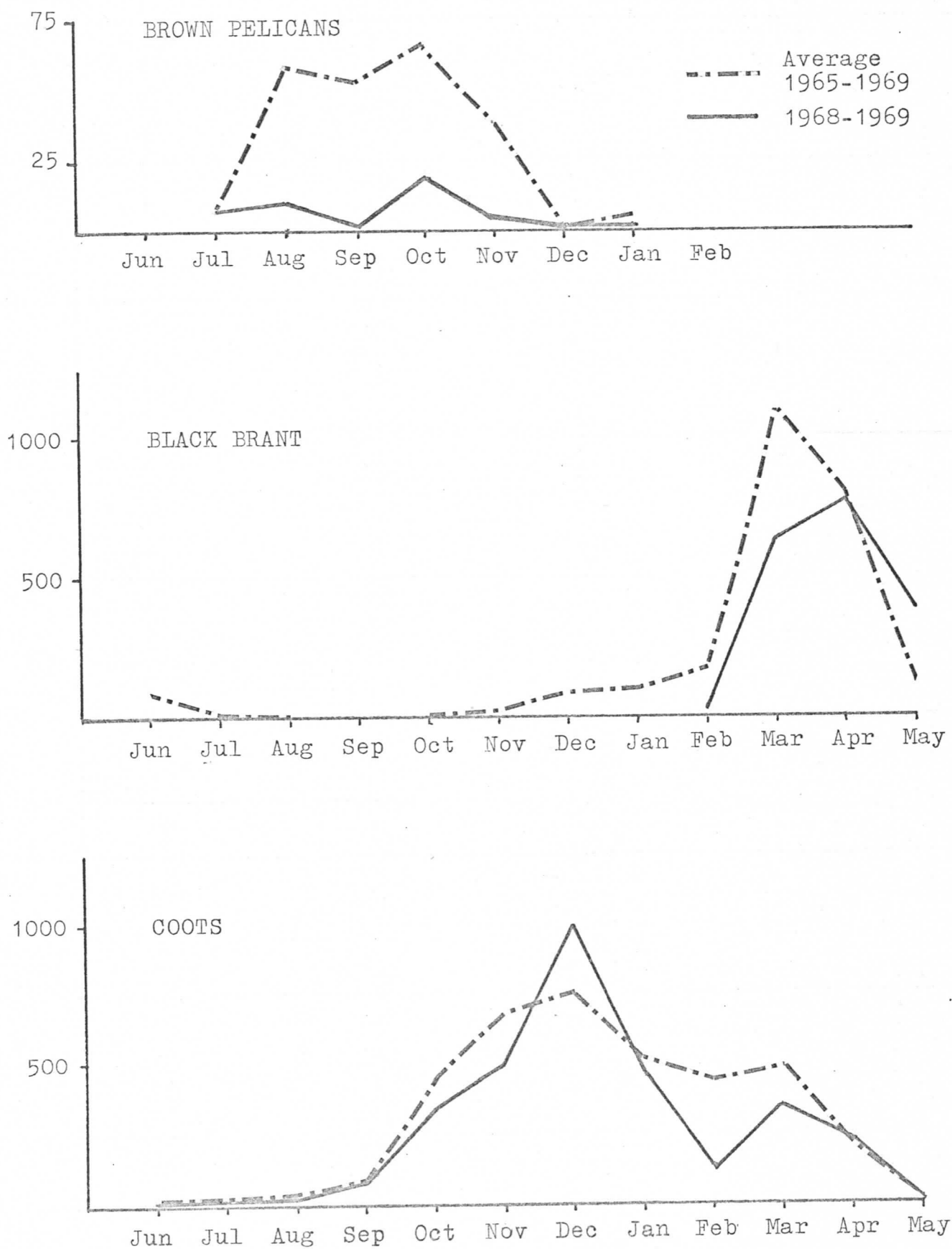


FIG. 4. MONTHLY ABUNDANCE OF SHOREBIRDS AND DUNLIN

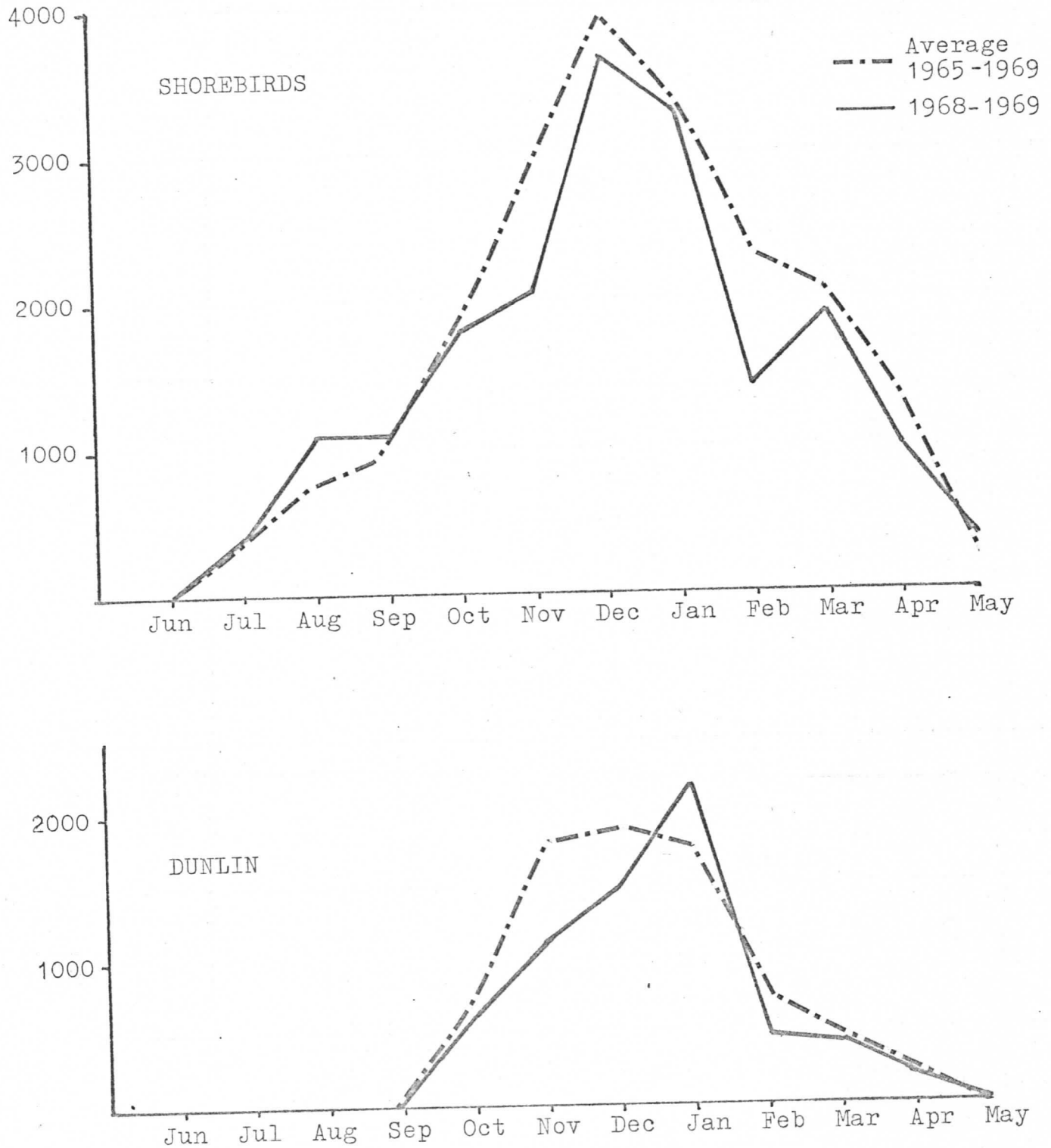
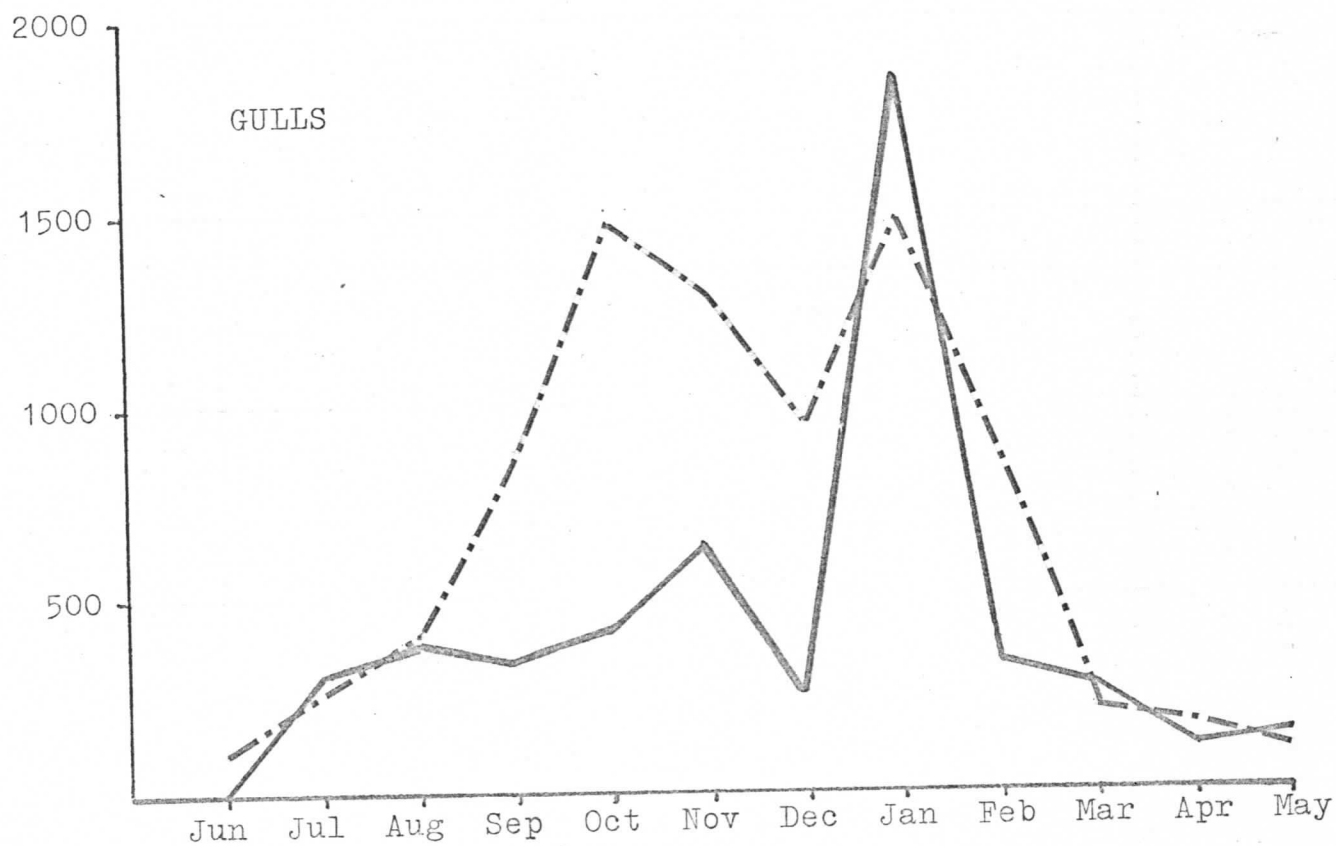
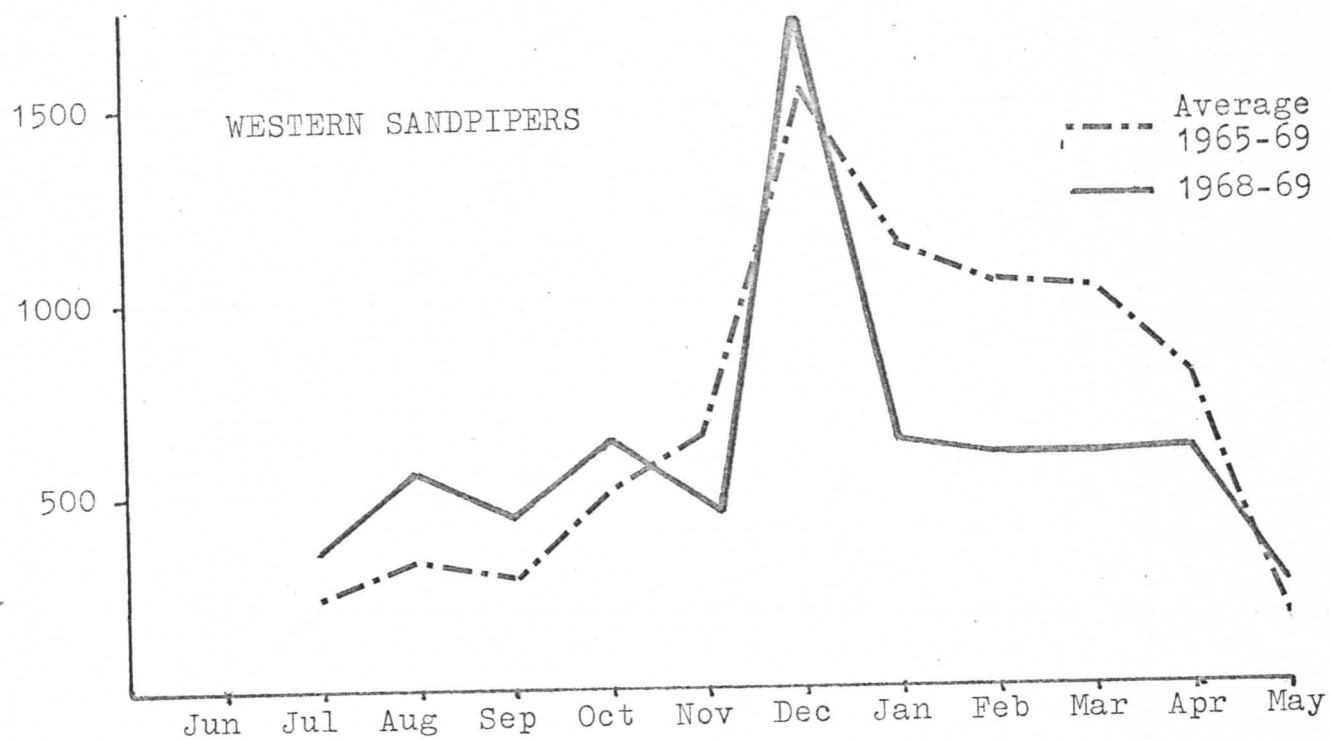


FIG. 5. MONTHLY ABUNDANCE OF WESTERN SANDPIPERS AND GULLS



RESULTS AND DISCUSSION - DISTRIBUTION NOTES

See Table 2 and Figs. 2 - 5

Loons (Gaviidae)

The estero is not a favored resting place for loons. Although the migratory path of thousands of loons each year takes them past the Bird Observatory's headquarters at Palomarin and close offshore through Drake's Bay very few of them use either Limantour or Drake's Estero.

The most noteworthy observation in this group was a Yellow-billed Loon on March 4. This is only about the ninth record of the species in California, the first having occurred in Tomales Bay in December 1967. The annual pattern for the other species was as expected; the Common Loon occurring in all months except June and the Arctic and Red-throated irregular and unpredictable but always in very small numbers.

Grebes (Podicipedidae)

The Western Grebe had a remarkably poor year at Limantour. In the 1966-67 season the high count was 256; in 1967-68 it was 103 and in 1968-69 it dropped to only 9. It is difficult to explain this drop since large flocks were seen along the coast.

The Pied-billed Grebe is one of the few species that breed at Limantour. Muddy Hollow Pond (area 1) and the pond to the east of the paved access road (area 2) produced two broods each in the spring of 1969. The usual small movement of what are presumably post-breeding wanderers was recorded in September, October and November.

Pelicans (Pelicanidae)

Although Limantour is not a major resort of the Brown Pelican, there is ample evidence in our census figures of the last four seasons that numbers have declined alarmingly. Table 3 compares monthly averages from 1965 to 1969. This picture is, of course, consistent with observed trends throughout California as a result of the influence of pesticides on breeding success. At present the Brown Pelican is in the "Status Undetermined" class of the U.S. Fish and Wildlife Service Rare and Endangered Species List, but it seems inevitable that it will be classified as endangered. The White Pelican, an inland breeder which visits the coast in late summer and fall, appears to be holding its own.

Table 3. Monthly Averages of Brown Pelicans at Limantour Estero

	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1965-66	20	114	182	206	138	4	19
1966-67	7	86	6	33	5	4	-
1967-68	-	22	18	8	5	1	-
1968-69	8	10	1	18	4	-	-

Cormorants (Phalacrocoracidae)

The Double-crested Cormorant is the only member of this group consistently seen on the estero. The bay to the north (area 8A) is strongly favored for feeding, but the adjacent portion of the main estero is also used. The other two species recorded have an obvious preference for deeper water and are only seen at the mouth of the estero (area 10).

Geese (Anserinae)

The importance of Limantour as a resting place for the Black Brant has been emphasized in these reports. The pattern of migration has been very different from season to season, sometimes with massive flocks accumulating and sometimes much more spread out with smaller fluctuations, as in the 1968-69 season. It is abundantly clear, however, that the north arm of the estero, with its extensive beds of eelgrass provides a vital feeding area for this sensitive species. Most other waterfowl have a wide diet tolerance, embracing plant and animal matter, but the Black Brant eats eelgrass (*Zostera* sp) and sea lettuce (*Ulva* sp) almost exclusively according to Einarsen (1965). Both of these foods are found in Limantour and in Drake's Estero, which together with Tomales Bay, constitute the only good habitat for Black Brant between Morro Bay and Humboldt Bay. The preservation of the eelgrass beds should therefore be a major concern in any plan for the management of Limantour Estero or Drake's Estero. This question is discussed in more detail in the section of this report dealing with management and development problems.

Dabbling Ducks (Anatinae)

The 1968-69 season saw a much less erratic distribution of dabbling ducks with no repetition of the Pintail invasion of last season. As in every season except 1967-68 the American Widgeon was the most numerous of this group, although the high count of 337 was less than half of the lowest previous peak figure (1966-67). As in previous years the Widgeon were found in Muddy Hollow Pond (area 1) early in the season but tended to move to the east end of the estero (area 5) later in the year.

Numbers of teal were unusually low this season; the Cinnamon Teal, for instance, never numbered more than five as compared with last season's unusually high peak of 56.

Diving Ducks (Aythinae)

Although a substantial number of Bufflehead in December brought the figures for that month above the average for the four years of the census, this group had a poorer season than in 1967-68. One of the contributing factors was the virtual absence of the Canvasback as a wintering species, a phenomenon noted elsewhere in the state. Only seven appeared as against up to

JS

209 in previous years. Bufflehead and Ruddy Ducks, too, were rather below their usual numbers. All these species seem to fluctuate greatly from year to year, but the Surf Scoter and the White-winged Scoter in contrast show remarkably little variation. The rare Oldsquaw made its second appearance in four census seasons; two individuals were seen, one of which stayed in the estero from February through April.

Coot and Rails (Rallidae)

As in previous seasons coot were abundant on Muddy Hollow Pond and in the main arm of the estero, but although fall numbers were high the population declined more rapidly than usual in winter and early spring. There was no record this season for the Common Gallinule although the species may have bred here in the 1966-67 season. The Sora was the only rail species recorded.

Plovers and Turnstones (Charadriidae)

The Semipalmated Plover is virtually a resident species, occurring consistently throughout the year although there are different overlapping populations--nonbreeding birds in summer and wintering birds later in the year. The high count of 116 Snowy Plovers on February 4 was the highest number recorded on our censuses. The American Golden Plover, a rare fall migrant, was recorded five times this season, including unprecedented December and February records. Although they are known to winter regularly as far north as San Diego it does not seem likely that these birds wintered here. The Black-bellied Plover, a regular wintering bird on the estero, has maintained fairly consistent numbers over the four census seasons with the 1968-69 season a little below average. Black Turnstones maintained the same high numbers in 1968-69 as in the previous season.

Sandpipers (Scolopacidae)

The Long-billed Curlew, an uncommon and erratic migrant, was recorded in eight months during 1968-69, a quite unprecedented number.

The Least Sandpiper's status as a wintering bird has become clearer from the four seasons of data and the Observatory's banding records. It appears that the Least appear on the estero in July after breeding, build up to their stable wintering population of 300 to 350 by September and stay on until December or January. At this time the northward migration to the breeding grounds starts and the main resident population begins to leave. The numbers are sometimes swollen in March or April by transients moving through from the south. The remarkably high recapture rate from our banding during 1968-69 demonstrates that this species is far more faithful to the area than either the Dunlin or the Western Sandpiper.

The temporal distribution of the Western Sandpiper and Dunlin, when represented on a graph of the average numbers over four years, seems to be regular with a single peak for both species occurring in December or January. In any given season, however, the pattern will be less regular. The Western Sandpiper seems to show a much wider fluctuation of numbers from month to month, while the Dunlin is more predictable.

The problems of separating the two dowitcher species in the field and their ecological separation and distribution have been greatly clarified during the course of the study. A detailed study of these questions (Lenna 1969) was published in the Observatory Bulletin No. 13, September 1969.

Sanderlings were recorded in every month during the season, but the pattern of their distribution on the estero is inexplicably erratic.

Gulls and Terns (Laridae)

The rapid changes of population from day to day and even from hour to hour in this group make it particularly risky to generalize about trends. Limantour is not as attractive to gulls or terns as several other places along the coast. The Western Gull, for example, with a breeding population of 20,000 on Southeast Farallon only 20 miles from the estero, is never seen in the numbers that this proximity might suggest. Numbers were generally lower in 1968-69 than in the previous season, especially in the Ring-billed Gull. The apparent demise of the Brown Pelican gives rise to speculation on the future of the Heermann's Gull which is a pelican parasite. A comparison of Heermann's Gull numbers over four years does not show a corresponding decline, and on present evidence it seems likely that this gull will hold its own as a northward migrant after breeding in Mexico.

The appearance of a flock of 20 Elegant Terns on October 25, 1969, was surprising. This species, although a regular post-breeding wanderer in the San Francisco Bay area, is unusual further north and this was an exceptionally large number.

RESULTS AND DISCUSSION - SHOREBIRD BANDING

The results of the shorebird banding for 1968-69 are shown in Table 4.

Table 4. Shorebird Captures at Limantour Estero 1968-69

	1968				1969		Total
	8/24	9/28	10/26	11/24	3/8	3/29	
Least Sandpiper	17	18(3)	10(4)	8(3)	4(3)		70(13)
Western Sandpiper	12	10	16(1)	5	44(2)	34(1)	125(4)
Dunlin		5	100(2)	28(5)	17(3)	13(2)	175(12)
Sht.-bld. Dowitcher	3						3
Lg.-billed Dowitcher		1		1			2
Black Turnstone		1					1
Semipalm. Plover		1	1				2
	32	39	134	50	73	50	378(29)

Figures in parentheses show recaptures.

Heavy rain in December 1968 and the early months of 1969 severely curtailed this program and activity on November 24 was cut short by a sudden storm.

Although the number of captures is disappointing, the proportion of recaptures (29 out of 378 = 7.7%) is high and significant. The corresponding figure for a concurrent program in Humboldt Bay (0.4%) gives some idea of the potential of Limantour as a study area; a substantial yet easily observable population in a confined area offers unexcelled opportunities.

The recapture percentage in the Least Sandpiper was a striking 18.6% (13 out of 70). Recaptures in this species since 1965 have shown a remarkably pronounced tendency to return in successive seasons--a bird captured in September 1965 was recaptured in December 1967, another first banded in December 1967 was recaptured in January 1968, November 1968, and March 1969.

Experience with the Dunlin has been rather different; although the recapture proportion is high (12 out of 175 = 6.9%) we have had only one recapture so far from one season to the next, but

four recaptures in March 1969 from December 1968 indicate that much of the population probably migrates no further south than Limantour.

The Western Sandpiper presents a strong contrast to both the above species. Although the relatively low recapture rate (4 out of 125 = 3.2%) may be due in part to Westerns not roosting by night in a constant place within the estero as Least seem to do, the capture total is high and seems to indicate a definite trend. There have been two recaptures one or more seasons apart, but the paucity of recaptures in the same season, in combination with the wide fluctuation in numbers between censuses, strongly suggests a rapid turnover of population.

FIG. 6. AREA PREFERENCES OF SHOREBIRDS

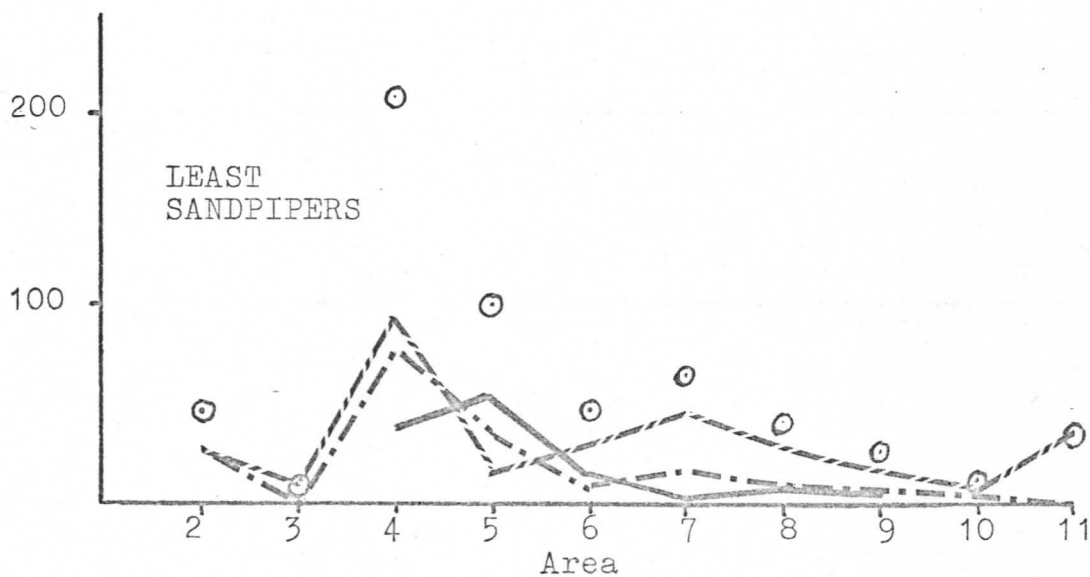
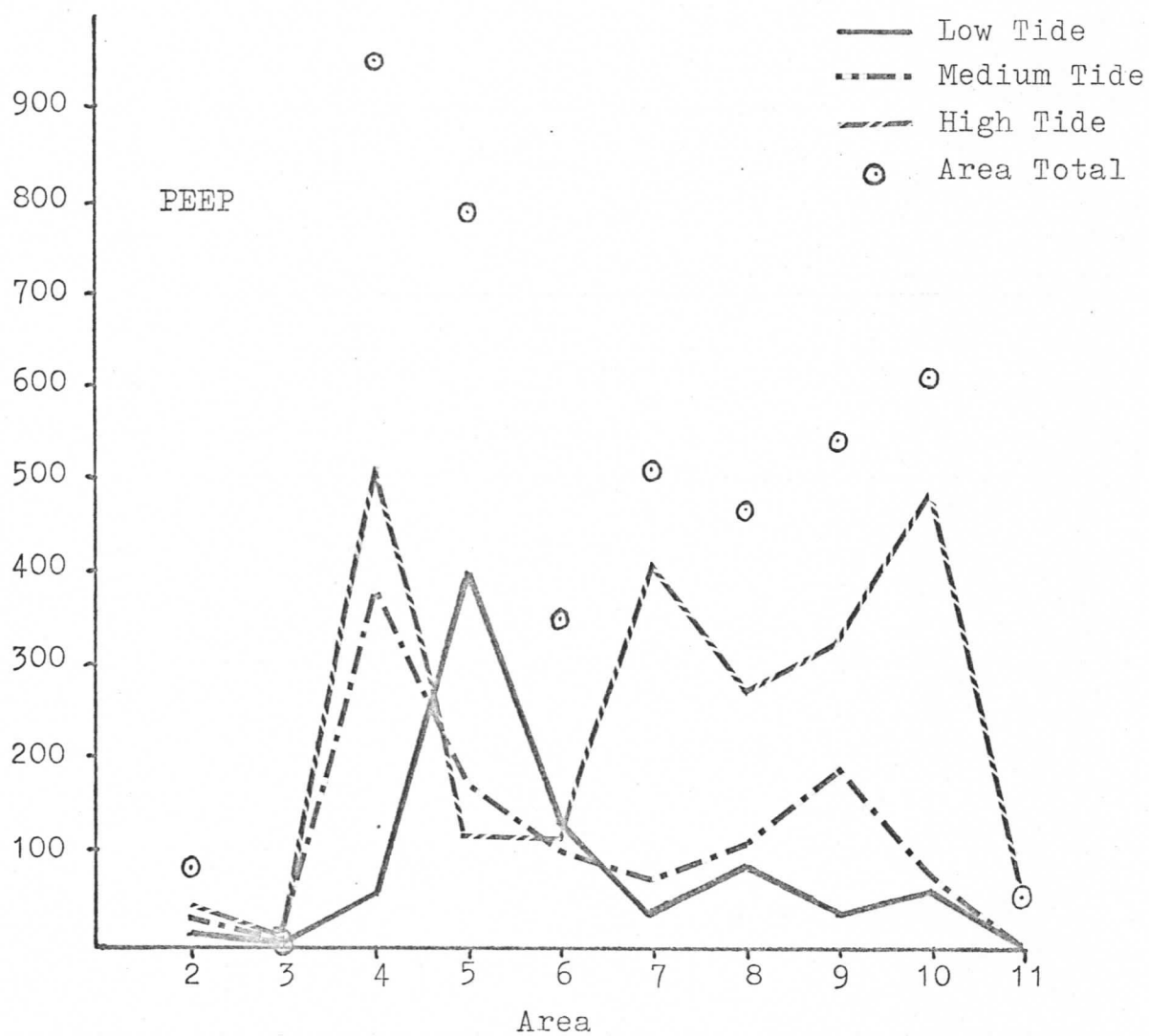
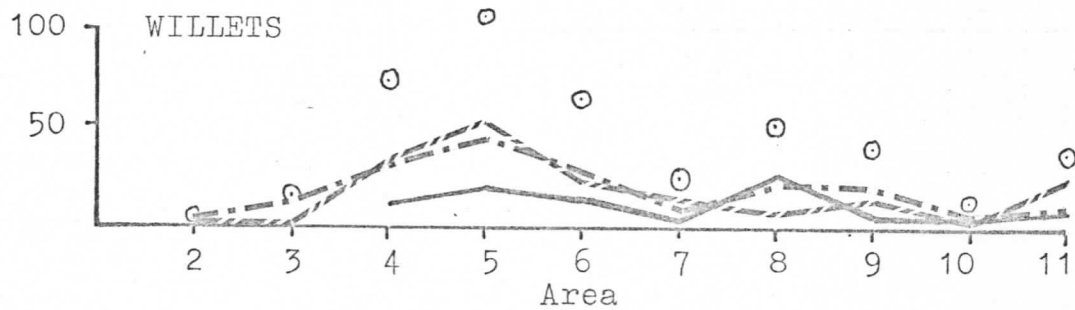
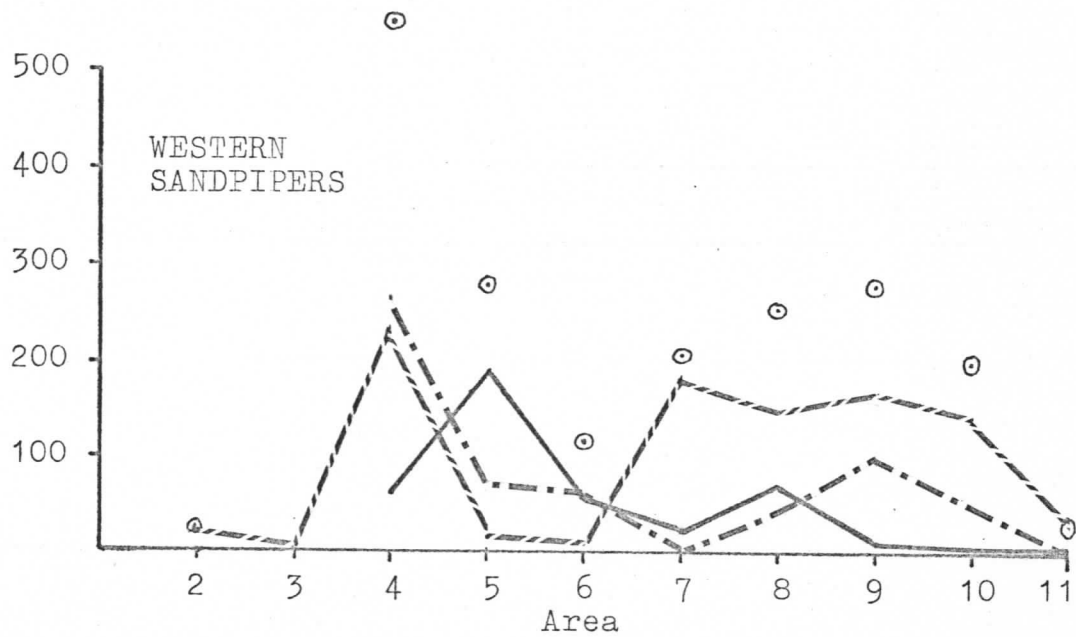
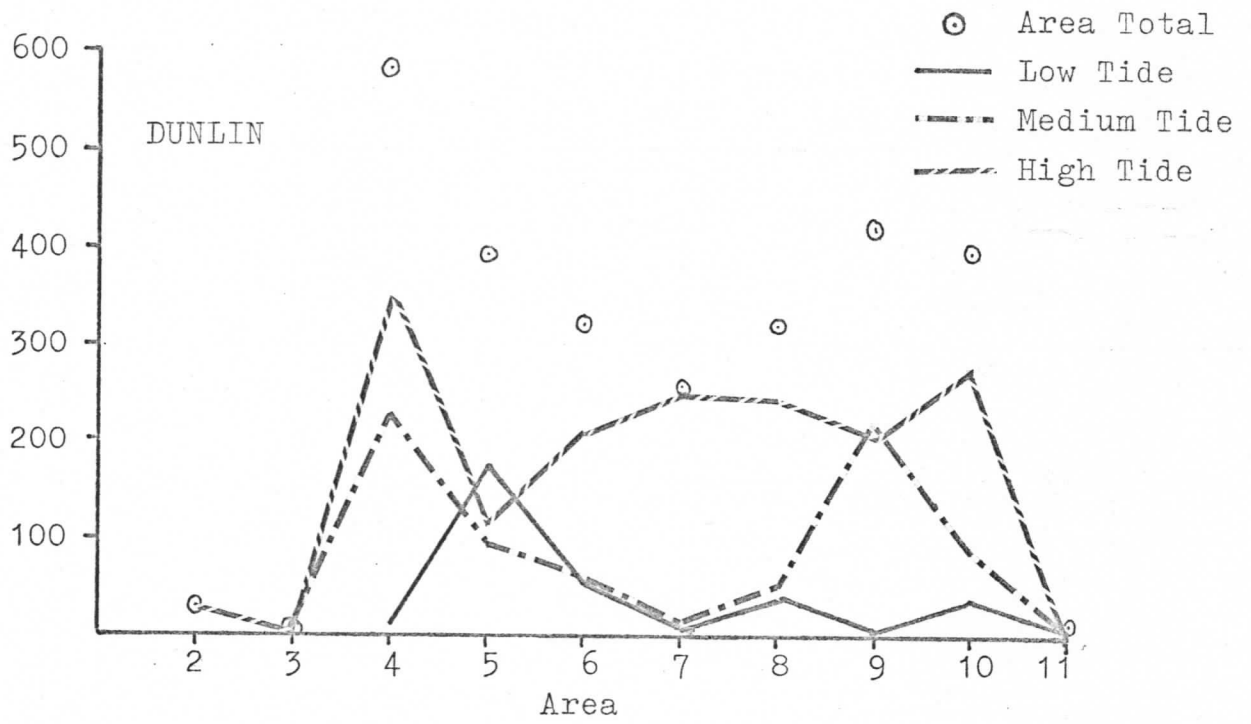


FIG. 6 (Cont'd). AREA PREFERENCES OF SHOREBIRDS



ANALYSIS OF CENSUS DATA

The ground census technique used at Limantour was devised with a view to recording as much usable data as possible from the observations. While not overloaded with fine detail, the census included information on time of day, tide, activity of the birds, and habitat type. It was felt that the information obtained at Limantour had an obvious general application in addition to its immediate purpose, and that, especially in the light of the variety of habitat, the data should be analyzed quantitatively in a manner that would be understandable to and usable by agencies concerned with any kind of wetland habitat.

A question of obvious interest in an estuary is the influence of the tide upon use of an area and population density of various species within the area. Our first computer printout, therefore, was concerned with the distribution within the estero of shorebirds, the group most clearly affected by the tide.

The Tidal Cycle at Limantour

Some understanding of the tidal cycle is necessary for a meaningful interpretation of the data output from our computer program. In the normal daily pattern of the tides in the San Francisco Bay area, two high tides--one very high and the other moderately high--alternate with low tides of similarly differing heights. Thus on July 6, 1969, for example, the predicted tide times at Fort Point, San Francisco, with heights in feet above the datum line were as follows:

0012	1.8	0548	4.0	1130	1.2	1830	5.8
------	-----	------	-----	------	-----	------	-----

The graph of height against time at Fort Point is a more or less regular sine curve.

In an estuary, however, the pattern is different. The restriction of flow at the mouth and the drag created by the banks and the bottom tend to retard both incoming and outgoing tides. In a long and narrow estuary like Limantour there is a marked difference in the time of both high and low tides according to the distance of a point from the mouth. Although detailed observations for points near the mouth are lacking it seems clear from many casual observations that there is a delay of the order of two hours between the mouth and area 5, some two miles directly along the main channel to the east. Prolonged observation on July 3, 4 and 6, 1969, made the unevenness of the curve quite clear: the low tide on the days of observation occurred about two hours after the time predicted for Fort Point while the high tide occurred six minutes before the time predicted for Fort Point on one day and six minutes after the Fort Point time on another day. It was clear that many factors such

as the strength of the wind affect each day's tides and that any correction factor applied to a tide graph would have to represent a simple compromise. For data processing purposes, therefore, the tide on any given day was assumed to turn at the same time as Fort Point on a high tide and two hours later on a low tide.

These values make an interesting comparison with the tidal differences given in the tide tables for Point Reyes (presumably at the lighthouse) about six miles southwest of the mouth of Limantour Estero, where the high water occurs 65 minutes before Fort Point and the low water 37 minutes before. The lag of over two and a half hours between Point Reyes and area 5 at Limantour gives some idea how strong the friction in the narrow estuary is. The strong prevailing northwest wind is clearly a major factor in accelerating the incoming tide and retarding the outgoing tide since the estuary runs directly east-west with the mouth at the west end.

Data Processing

In order to analyze the data obtained from the ground censuses made by the Observatory, a computer program was established. Since 1966 data has been recorded within habitat areas, as described in detail in Table 1, on forms with headings as shown below:

SPECIES	AREA	WATER		MUD AND SHAL. WATER		MARSH		SAND OR DUNE		FLYING		TOTAL
		Feed	Rest	Feed	Rest	Feed	Rest	Feed	Rest	W	E	

A computer punch card was made for every observation and each carries information on date, time and place, tide data for the day of the observation, the species observed, its activity (resting or feeding) and the general type of habitat where it was seen.

The program was devised by Mr. Norman Besman of the Pacific Northwest Forest and Range Experiment Station (US Forest Service) in Berkeley. One important feature contained in it was interpolation for tide height; using the times predicted in the tide tables and the time of the observation, it was possible to establish with reasonable accuracy the state of the tide for any single observation in any census.

Since the effect of the tide is most marked in areas 4 and 5, the state of the tide in these areas was chosen as the basis for analysis of shorebird distribution. Observation had revealed three more or less distinct tidal situations as follows:

1. Low Tide. The water level is less than 1.5 feet above the datum at Fort Point. At this level the flats in area 4 are all fully exposed and the main channel through area 5 is cut off altogether from the effect of the tide. Once the level drops

below about 1.5 feet there is no flow at all between areas 4 and 5. Over 40 acres of flat are exposed in area 5. It should be pointed out that on some tidal cycles the "low water" is higher than 1.5 (sometimes over 3 feet) in which case this situation does not occur.

2. Middle Range. The water level is between 1.5 and 3.5 feet. Within this range the tidal flats in area 4 remain fully exposed, but in area 5 the tide reaches the edge of the Salicornia marsh at the top of the range covering up the flats completely.

3. High Tide. The water level is over 3.5 feet. As the tide rises above 3.5 feet the 15 acres of flats in area 4 begin to be covered, but it is not until the water reaches about 5 feet that they vanish altogether. Above 3.5 feet the water spills over onto the marsh in area 5. At the highest tides (i.e. those over 6 feet) the marsh in both areas is flooded and usable only by the larger shorebirds such as Willets.

Since it made no real difference in the lowest tide range whether the tide was rising or falling, no distinction was made in analyzing this range, but for both the other divisions the computer was asked to distinguish between a falling and rising tide within the given range. As a result of the unevenness of the tide curve with a slow ebb and fast rise, the sample sizes for a rising tide were smaller than those for a falling tide.

A selection of shorebird species and groups was made as follows:

1. Small Sandpipers ("Peep"). This group was a composite of all observations of Least Sandpiper, Dunlin, and Western Sandpiper separately or collectively, including observations of small sandpipers not assignable to a particular species within this group.
2. Least Sandpiper.
3. Dunlin.
4. Western Sandpiper.
5. Willet.

Discussion (See Fig. 6)

1. Small Sandpipers ("Peep"). It can be seen at once that there is a strong preference in this group for areas 4 and 5, the latter being preferred at low tide and the former in the middle ranges and at high tide. Area 5 has a substrate of sandy mud which is known to be a rich combination (e.g. Reid 1965) and our substrate analysis indicates that this area is indeed the richest in invertebrates. On a rising tide most of the sandpipers will stay in area 5 until the substrate is covered or at least until the pressure for space on the diminishing flat

becomes intolerable. Most of the soft 15-acre mudflat in area 4 remains accessible until the tide level exceeds five feet above the Fort Point datum.

As the tide recedes from its peak the elevated mudflat in area 4 is the first to become exposed, in fact, through perhaps half the tidal cycles in the estero it is never fully covered. In the middle ranges of a falling tide, area 4 is favored, presumably because of the limited space available on the flats in area 5. It seems that the preference for the sandy mudflat (area 5) over the softer saturated mudflat is explained simply by the richer invertebrate life in the sand-mud combination and not by vertical movement of the animals within the mud, since a study in Tomales Bay (Johnson 1967) showed negligible vertical movement with the tide on a saturated flat comparable to area 4.

The prominence of the areas toward the east end of the estero at high tide is largely explained by birds resting on the dry sand flats as the tide covers the preferred feeding areas, although the flats in areas 8, 9, and 10 are used for feeding, particularly on a falling tide.

2. Least Sandpiper (*Calidris minutilla*). The heavy reliance of this species on area 4 is obvious from the graph. Observation confirms that Least Sandpipers are almost always to be seen on the mudflats in this area, and they show a marked reluctance to leave. Of the three "peep" species the Least, with its short bill ill-adapted for deep probing seems to be under most pressure to feed when exposed substrate is available. This pressure is most noticeable at the highest tides when Least can be seen running along pieces of floating driftwood looking for insects. It is significant that the pond to the east of the paved access road (area 2) is more consistently used by Least Sandpipers than by any other shorebird.

3. Dunlin (*Calidris alpina*). Although formerly placed in the same genus as the Least Sandpiper, this species, with a bill twice as long, has much more flexible feeding habits. This is demonstrated most clearly by the pattern of its distribution at high tide when the expected preference for area 4 is much less strong than that of the other small sandpipers. There appears to be quite a regular interchange of Dunlins between Limantour and Drake's Estero and it is most likely that the high averages at high tide are swollen by birds from Drake's.

4. Western Sandpiper (*Calidris mauri*). As might be expected this species also strongly prefers areas 4 and 5, but it is more flexible in its feeding than the Least Sandpiper, making greater use of the flats toward the mouth of the estero (areas 7-10) for feeding. Of the three "peep" species analyzed, the

Western has least use for the freshwater ponds at the east end (areas 2 and 3). As with the Dunlin there is obviously an interchange between Drake's Estero and Limantour in this species.

5. Willet (Catoptrophorus semipalmatus). The Willet is the most versatile of the shorebirds using the estero; it has a long enough bill to explore the mudflats to the full and long enough legs to wade or cross the salt marsh with equal facility. The distribution graph is noticeably different from those of the "peep." The Willet's ability to forage on the salt marsh on the abundant insects and small crabs (especially the shore crab Pachygrapsus crassipes and the mudflat crab Hemigrapsus oregonensis) means that they can use area 5 at high tide, switching readily from mudflat to Salicornia. It is significant that they are less numerous at high tide in the areas used for resting by small sandpipers (areas 7, 8 and 9), preferring to preen and rest on the mudflats or to forage on the ocean beach (area 11) when food is less readily available.

These graphs represent a very small sample of the preliminary output from the computer program. Quantification and comparison of census data by computer offer possibilities that we have barely begun to realize. The method of censusing we have used has given us wide scope for analysis, since it takes into account virtually every factor that could influence the presence or distribution of a species at a given time.

The analysis of the shorebird group will be refined to determine population density of each habitat area by tide height, and to give an estimate of the number of bird-days of use for each month. From these figures, viewed in comparison with data from elsewhere in the state, it will be possible to give an informed estimate of the value and carrying capacity of shorebird habitat of various kinds throughout the state.

MANAGEMENT AND DEVELOPMENT

The Present Situation

At the time of writing the position of Limantour Estero as part of the Point Reyes National Seashore is unclear. The only access for motor vehicles is by a road which traverses private property and is closed off on weekends by the local residents. Even with this limited access the impact of human use is disturbingly evident.

One of the most disturbing developments in the last two years has been the increasing use of cars and dune buggies on the beach and even on the marsh. On the beach the presence of motor vehicles is very annoying to walkers but on the marsh the tire tracks of vehicles do permanent damage that accelerates the erosion of the sandspit and poses a real physical threat to the environment.

Equally disturbing is the rise in poaching of deer, ducks, and brnat. Although Park Service rangers who patrol the area are doing a commendable job in this regard and although their efforts are being supplemented by reports from local residents and Observatory staff, the proliferation of hunting is difficult to check with the Park Service staff so obviously overextended. Whatever the future of Limantour Estero we strongly urge that it be given increased ranger coverage to curb present abuses and to forestall further deterioration of the environment.

Master Plan

The existing master plan for Limantour Estero (NS-PR 3025A) proposes a spill dam across the main channel to impound some 100 acres of water surface at the east end of the estero (areas 4 through 6). This proposal seems highly questionable to us for three distinct reasons:

1. The combination of dredging and fill would cause erosion.
2. The strong, cold northwest winds and fog make the area unattractive for boating and swimming.
3. Irreplaceable wildlife habitat would be destroyed.

These will be considered in detail below:

1. The development as proposed requires extensive dredging to make the shallow main channel deep enough for boating. It also necessitates the complete destruction of the salt marsh by filling and grading to form a sandy beach. The physical consequences of this action could be grave since the erosion which so clearly affects the west end of the estero could easily make further inroads at the east end. The combined effect of wind and tide

can be seen clearly in aerial photographs with the northwesterly direction of the prevailing wind apparent from the configuration of the dunes. It is clear that the tightly integrated mass of vegetation from area 6 eastward is more resistant to erosion. With the Salicornia of the salt marsh being replaced by an artificial sandy beach and the inevitable settling in the dredged channel it is doubtful whether erosion could be resisted. It is also highly likely that the removal of this vegetation would cause seepage into the coarse sand of the spit. The windbreaks and "stabilized dunes" in the master plan would serve little purpose and their provision betrays a fundamental lack of knowledge of the area, because their placement is behind the beach away from the prevailing west northwest wind.

2. The climate of the Point Reyes National Seashore is by no means consistently warm. The situation of Limantour Estero which runs east-west and is backed by cliffs up to two hundred feet high forms a natural funnel for the strong prevailing, west northwest winds blowing across the peninsula through inlets such as Barries Bay, across Drake's Estero and into Limantour Estero. The effect of these can be exhilarating but as a concomitant to boating and swimming they might prove more than the general public would be willing to tolerate.

3. The objections raised so far have concerned purely physical impracticalities inherent in the spill dam scheme. It must be emphasized that there are far more serious objections to this or any other scheme involving artificial manipulation of the water level or interference with the natural sequence of tides in the estero. It is safe to predict that all the habitat for Black Brant and over half of that for dabbling ducks, coot and shorebirds would be destroyed at one stroke if the dam were installed. Habitat damage result from the change in the water level would be threefold:

a. Submerged vegetation especially eelgrass, would no longer be available to surface feeders such as Black Brant and dabbling ducks. The estuary's eelgrass beds which are concentrated in the bay to the north and in the middle reaches extend to over 70 acres. Eelgrass supplies over 80 per cent of the winter diet of the Black Brant (Moffitt 1941) and its presence is vital to the survival of this sensitive species. Only in times of eelgrass shortage will it resort to alternative diets such as sea lettuce (Ulva sp) and, on rare occasions, Salicornia (Einarsen 1965; Cottam et al. 1944; Moffitt 1941) and even grain (Leopold and Smith 1953). Since brant do not dive and are diurnal, they must have a supply of eelgrass close enough to the surface to be within their reach during a daylight low tide. The impoundment of water at the eastern end of the estero would have an inevitable effect on the level of the water to the west of the dam, diverting an incoming tide into the bay to the north and raising the level of the water above the main expanse of eelgrass

beds in areas 8, 8A, and 9 by many inches. This would critically affect the ability of this delicate species to feed.

In this context, it should be pointed out that the Drake's Bay area together with Tomales Bay and Bodega Bay provides the only major resting place between Morro Bay and Humboldt Bay on the northward migration of the Black Brant. The loss of any of its few remaining feeding areas could jeopardize the species.

A further significant plant resource of the estero is sea lettuce (Ulva sp) which is found in quantity on the intertidal flats, especially in areas 4 and 5. To the hundreds of surface feeding waterfowl using the main body of the estero the Ulva is a useful food which is available to them both by reaching below the surface in shallow parts of the main channel as for instance the abundant wintering flocks of coot and widgeon do in areas 5 and 6, or by foraging on the exposed flats, especially in area 4 (coot and Gadwall). It is attractive also to certain shorebirds, particularly the Black Turnstone, whose foraging relies heavily on the invertebrates in and around the sea lettuce. Quite apart from its immediate role as a source of food for birds, sea lettuce, according to a recent study in Bolinas Lagoon (Gustafson 1969), has a vital function as a link in the food chain, nurturing young fish and a wide range of invertebrates, amphipods, shrimps and crabs.

Obviously raising the water level would mean that the sea lettuce was not available as bird food; it would also mean that its productivity, which depends on the tidal cycle would be effectively terminated if indeed the plant survived at all.

b. The second major ecological disaster which would result from the spill-dam development would be the destruction of the Salicornia and Spartina marsh areas. As discussed earlier, there would be many physical difficulties in the scheme, but whatever solution is adopted the salt marsh bordering areas 4, 5 and 6 would inevitably be destroyed. If the water level were raised to cover the marsh it could not survive. A study in San Francisco Bay by Hinde (1954) showed that Spartina and Salicornia cannot tolerate prolonged immersion nor can they endure the lower salinity that would result from the impoundment of the east end of the estero.

A more clearly inevitable result is the loss of the productivity of the marsh. In all-round productivity salt marshes are almost unsurpassed. The elimination of the salt marsh would be felt all the way along the food chain up to and including man (see quotation at the end of this section).

c. The most obvious effect of the artificial lagoon would be the elimination of the intertidal flats. As a matter of simple observation, the feeding of virtually all shorebirds depends on exposed substrate. There is a perfect illustration in the

study area itself of a dammed area which has become a sterile shorebird environment. The Muddy Hollow Pond (area 1) created within the last fifteen years by damming an area of Salicornia marsh is of no value at all to shorebirds; there are no flats and the salt marsh vegetation has been succeeded by typical pond growth. Of course, it could be argued that the impoundment might create more habitat of the same type as Muddy Hollow Pond and the pond behind the dam further west along the estero, but there is already ample habitat of this type in the area and elsewhere in the county and in any case constant human disturbance would make the area uninhabitable. An example of the kind of sterile environment created by impoundment within a tidal area is the lagoon in the Seadrift development at Stinson Beach Marin County. Our aerial censuses have shown that this artificial lagoon is much less attractive to birds than the adjacent portions of Bolinas Lagoon, of which it was once part, and incidentally, it provides little apparent human recreational value.

In summary then, any development involving impoundment, manipulation of the water level or interference with the natural sequence of tides would destroy the whole estuarine nature of Limantour Estero. In the process several extremely productive natural resources--especially the eelgrass, the salt marsh and the intertidal mudflats--would be altered irreplaceably. With Limantour especially there is no possibility that these values are replaceable since Limantour and Drake's Esteros are the only unspoiled estuaries left on the whole west coast of the United States. The current realization of the special role of estuaries is timely, for the unique combination of features--the mixing of waters of different salinity, the especially rich vegetation, the enormous variety of invertebrate life--is highly productive. An emphatic statement of the relevance of this productivity to human needs comes from the 1968 USDI report on Water Quality Criteria:

...more than half of the over 4.5 billion pounds of fisheries products harvested by U.S. fishermen annually is derived from animals dependent for their existence on clean estuarine waters during some part or all of their life cycle.

It seems to us that there is ample evidence that on bird values alone Limantour Estero should be preserved in its natural state and that on more general considerations it is imperative that the last remaining natural estuary on this coast should not be yielded lightly. The creation of a sterile artificial recreation area in a climatically uncongenial spot does not strike us as approaching the gigantic human need which alone might outweigh these considerations. While we are aware that the Point Reyes National Seashore, according to its Establishment Act, was set up "for purposes of public recreation, benefit, and inspiration..." we feel strongly that the quality of recreation in this case cannot outweigh a natural estuary which would provide benefit, recreation and inspiration of an irreplaceable kind.

SUMMARY

Point Reyes Bird Observatory has completed four seasons of study on the birds of Limantour Estero. During this period detailed data have been taken on numbers and seasonal distribution of 108 species of water birds using the estero. Loons, grebes, pelicans, cormorants, herons and egrets, ducks, geese and swans, rails and coot, shorebirds, gulls and terns were included in the survey. Monthly average figures are presented for the 1968-69 season and compared with an average of four seasons.

The census has been based on a system of 12 area divisions made according to location and habitat type. The areas are described and evaluated in terms of resources and all-round habitat usefulness. From analysis of aerial photographs the acreage of each area and the amount of water, intertidal flat, marsh, sand, and eelgrass in each area was measured.

A computer program has been devised to analyze the census data. Observations were made to determine the pattern of daily tidal movements in order to show the distribution of shorebirds along the estero at different stages of the tide. A first computer run was made to elucidate this distribution, and a sample of the data output is presented and discussed.

An aerial census program has been instituted, covering Limantour Estero in conjunction with Tomales Bay, Drake's Estero, Abbott's Lagoon, and Bolinas Lagoon. Management and development of the estero are discussed and the National Park Service master plan of 1964-65 is given consideration in the light of the physical phenomena of the area and its habitat value. On physical counts it is thought to be impracticable for two main reasons: firstly, the development would bring about the destruction of the area through erosion; secondly, the strong prevailing wind would make the area unattractive for boating and swimming.

RECOMMENDATIONS

After four years of study there can be no doubt that Limantour Estero possesses very special value to wildlife. Although our study has concentrated on the birds and other animal groups have been considered only insofar as they affect the birds, it is clear that the estero is of unusual interest to the marine biologist, for example. (It is used as a study area for this purpose by the College of Marin.) The productivity of clean estuaries has been alluded to in general terms and although quantitative studies for Limantour are lacking, it can safely be assumed that this estuary, with its clean water and unobstructed tidal scour, is at least as productive as most. We feel, therefore, that the most urgent need here is for the production of fish and other marine life of long-term but nevertheless real and vital human importance, rather than the imperfect fulfillment of a more obvious need for mass recreation. There is no doubt at all that the general area can and should provide magnificent recreation, especially along the ocean beach, but we think the following restrictions should be made:

1. Public access by motor vehicles should be confined to the area east of the present access road.
2. Provision of public facilities for picnicking and fishing should be made in the same general area.
3. For the physical preservation of the area and in the interests of public safety, no vehicles should be allowed on the beach.

As pointed out in previous reports, the recreation facilities proposed for Limantour could be provided elsewhere on the Seashore. The upper part of Abbott's Lagoon, which is already dammed and is protected from the prevailing wind by high dunes, could provide a boating area of comparable size to that proposed in the Limantour master plan at much less cost and with small damage to wildlife. Tomales Bay was suggested as a possible site for swimming and boating development. Regular observation on our aerial censuses suggests that no irreplaceable habitat would be lost if parts of the west shore were developed.

We feel that Limantour Estero has enormous potential as an ecological study area. The growing awareness of natural resources and ecology suggest that this is far from being an idle dream. The sharp increase in numbers of visitors to places of interpretive interest in the area such as Audubon Canyon Ranch (18,000 in 1969) and Point Reyes Bird Observatory (over 5,000 in 1958, substantially more in 1969) speaks strongly for public acceptance of such a scheme.

The quality of Limantour's resources as an unspoiled estuary should be matched by an interpretive program of depth and vision. This challenge should be met.