

ASPECTS OF THE BEHAVIOR OF THE FORSTER'S TERN (STERNA FORSTERI)
NESTING IN COLONIES ON COBBLESTONE ISLANDS IN SOUTHCENTRAL WASHINGTON

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To the Faculty of Washington State University:

The members of the Committee appointed to
examine the thesis of JOHN ALAN HALL
find it satisfactory and recommend that it be accepted.

Chair

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Abstract

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Forster's Tern (Sterna forsteri) is typically a marsh nester. This study observed aspects of its behavior on cobblestone islands on the Hanford Reach of the Columbia River in southcentral Washington during the 1985 breeding season. Several experiments involving substitution trials at the nest site were performed to gain an understanding of recognition behavior in this species. Results from egg exchanges and alterations indicate a lack of egg recognition by adults. It is hypothesized that parent-chick recognition ability should develop prior to the onset of permanent brood mobility, which for this species occurred on the average at four days post-hatch. Limited chick experiments, however, allow only tenuous conclusions. Recognition by visual means appears unlikely. Chick comportment and vocalizations may be important for the parent-chick recognition process. Spectrographic analysis of the adult fish call indicates its potential for being a high information capacity signature system. The call is hypothesized to function as an individual identifier for an adult's chicks and mate. Information is also provided on additional adult calls and associated postures. Counts of active Forster's Tern nests indicate a declining population size for this species on the Hanford Reach. The primary

causes are hypothesized to be expanding California Gull (Larus californicus) and Ring-billed Gull (Larus delawarensis) populations and possible human disturbance pressures.

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Dedication

To all those who follow a dream until it becomes a reality.

INTRODUCTION

Typical of many other Larids, the Forster's Tern (*Sterna forsteri*) is a colonial nester. The proximity of nest sites to one another is dependent upon territorial behavior, substrate, and availability of nest sites. Though colonial nesting confers advantages of group protection from predators and possible induced synchrony of breeding when conditions are optimum, certain behavioral adjustments are required to ensure breeding success.

The modern view of Darwin's natural selection theory has been reduced to the concept of "survival of the fittest gene." The implications of this concept are that for an individual to realize its maximum "fitness" it must ensure that the highest percentage possible of its genes are passed onto succeeding generations. For a pair of breeding Forster's Terns this means production and survival of offspring.

Natural selection favors those behavior patterns that aid in the survival of a parent's offspring. In Forster's Tern, the raising of semi-precocial young should confer some selective advantage for survival. Forster's Tern young are capable of walking upon hatching but stay within the nest area for the first few days. Though chicks leave the nest site at an early stage, they are still quite dependent upon their parents for food, protection, and social education. In the egg stage, behavior patterns should ensure that the parents' eggs are incubated and protected, thus maximizing hatching success.

Quite often returns to the nest are made with the mate present. Mate recognition could also play a role in ensuring the correct nest is tended. A behavioral prerequisite then, imposed by colonial nesting, would be parental recognition of its own nest site, mate, eggs, or chicks. Failure to recognize these objects may result in a parent aiding the survival of an egg or chick which does not increase its own fitness. It may also involve increased energy being spent in agonistic encounters. Nesting on cobblestone islands in the Columbia River, where nest sites are often close, vegetation relatively sparse, and other visual cues minimal, the use of a combination of cues as a means of identifying one's own nest site, eggs, or chicks may be needed. Additionally, the need for parental care of chicks once the nest site is left, accompanied by the increased possibility of chicks from different broods intermingling, requires that recognition ability be acquired (either by the parents or by the chicks or both) prior to the chicks leaving the nest site.

Parental recognition of eggs and young has been studied in several species of the Laridae. Few studies, however, have been concerned with egg recognition. Buckley and Buckley (Bu 72) concluded that adult Royal Terns (*Sterna maxima maxima*) were capable of recognizing their own eggs, but features of the nest site and adjacent adults may also have had a significant effect on recognition. They also concluded that within a few days of hatching, parents recognized their own chicks (and vice-versa). Their chick results, however, were based on a small sample size (n=4). Davies and Carrick (Da 62) had similar conclusions concerning parent-chick recognition in the Crested Tern (*Sterna bergii*).

They did not, however, observe parental recognition of eggs, and only suggested chick recognition of their parents, providing no experimental evidence. Chick recognition in these species appeared to develop quickly, occurring in the first day or two post-hatching. This is consistent with the hypothesis of recognition occurring just prior to when it is needed. In both of the above species, the chicks leave the nest site within a few days to join a creche or nursery group (Bu 72 and Da 62). The presence of a creche makes individual recognition a necessity to enable parent terns to care for only their own offspring.

More intensive recognition studies have been performed with gulls. Miller and Emlen (Mi 75) found that parent Ring-billed Gulls (Larus delawarensis) were able to recognize their own chicks after seven to nine days post-hatching. They observed that chicks were mobile before this time, but did not begin to leave the confines of the nest site territory until day five. Prior to this recognition stage, there may be other features of the nest site gestalt that ensure a parent Ring-billed Gull provides for its own chick (Co 80).

Miller and Emlen excluded from their test sample, those broods that began wandering away from the nest site territories around the fifth day post-hatching. They recognized that by eliminating these broods (seemingly advanced in recognition ability), they probably biased their results. Early brood mobility resulting in permanent movement away from a nest site was also reported by Evans (Ev 66). His findings indicated permanent chick emigration from the nest site may occur as early as day three but was not common until days four or five.

As part of their experiment, Miller and Emlen (Mi 75) investigated

the basis of parental recognition. They identified the adult ability to recognize individual variations in chick physical appearance, developed over a week's time, as the dominant factor in recognition. They also indicated, however, that parental acceptance of a chick may be somewhat dependent upon the relaxed comportment of a chick that is exhibited when it is in a familiar physical and social environment. The importance of this phenomenon is discussed by Beer in his work with Laughing gulls (Larus atricilla) (Be 79). Beer concluded that chick discrimination by the parent was a result of the chick's ability to recognize its own parent, the chick's resulting behavior, and the adult's reaction to that behavior. The parent was not responding to individual chick characteristics. Beer only tested for voice cues, not physical appearance, which Miller and Emlen (M1 75) found to be the dominant factor.

In a recent paper by Beecher, et al. (Be 85), the results of the Miller and Emlen study appear to have been misinterpreted. In that study, parental recognition of chicks was experimentally demonstrated. Though chicks use vocal cues to recognize their parents (Ev 80), the parents used visual cues to recognize their chicks (M1 75).

Chick recognition of parents appears also to be important in ensuring the chicks own care (Be 85) and in the maintenance of brood cohesiveness, thus ensuring that parental energy is expended in raising their own offspring. Besides the Laughing Gull studies (Be 69 and Be 79), other researchers have found parental recognition by chicks in other Larid species: Black-billed Gull (Larus bulleri) (Ev 70), Ring-billed Gull (Ev 80), and Royal Terns (Bu 72), and suggested in Crested

Terns (Da 62). Recognition by the chicks was generally found to be through voice discrimination. Hutchison, et al. (Hu 68), observed that, for the Sandwich Tern (Sterna sandvicensis), there was enough interindividual variation between "the fish-call" of adults that the calls could be used as a basis for recognition. Similar experiments with colonial nesting Cliff Swallows (Hirundo pyrrhonota), Bank Swallows (Riparia riparia), and Pinyon Jays (Gymnorhinus cyanocephalus) demonstrated the use of call variations as a basis for recognition. Mutual recognition by calls occurs in these three species (St 83, Be 85, Be 81b, Si 85 and Mc 82).

The experimental manipulations performed as part of this study were substitution (cross-fostering) experiments. The adult tern is forced to either accept or reject a replacement egg or chick. As discussed by Shugart (Sh 77), the point at which rejection of a foreign stimulus increases significantly is not necessarily the time at which recognition occurred. The "contextual evidence as to kinship" (Be 82), (i.e., the nest site gestalt and the fact the substitution occurs in this environment) may for some time substitute for the recognition process (perhaps the whole egg stage and part of the post-hatch period). The parent may be reacting more to the finding of a chick or egg in a familiar setting and not specifically to the chick or egg. Thus, substitution trials may be beneficial in establishing that recognition may or may not occur in a species. If the trials are properly controlled, they can perhaps establish the basis for recognition but not accurately predict the time when recognition occurs (Sh 77). Additionally, substitution experiments cannot quantifiably evaluate the

effect on the recognition process made by the nest site gestalt.

The above is probably also true for the Miller and Emlen (Mi 75) experiments described previously for Ring-billed Gulls. Though chick recognition was demonstrated, the average time at which it was estimated to occur, seven to nine day post-hatch, may not be accurate. Evans (Ev 66) found permanent brood mobility away from the nest site occurred at three to five days post-hatch. Chick recognition of parents may be a factor. This may occur as early as day four in Ring-billed Gulls (Ev 66). Most investigators assume that recognition, if it occurs, whether by parent of the chick or vice-versa, must occur before the onset of brood mobility away from the nest site.

To determine the time at which recognition occurs, Shugart recommended the use of choice trials (Sh 77). The trials could be designed to eliminate the nest site gestalt as a factor in determining whether recognition occurred. Because of the disparities in recognition studies using substitution trials, Shugart hypothesized that recognition of progeny for colonial ground nesting birds in general was accomplished within the first five days of hatching and was not necessarily a species characteristic (Sh 77). This conclusion may be premature as selection pressures vary by species. The recognition signature used may vary in its complexity depending upon the amount of needed information capacity (Be 82). Studies to date indicate that species use different sensory modalities for the recognition process. Additionally, recognition may be unidirectional or bidirectional (Be 85); i.e., parent offspring recognition may be mutual or in only one direction (and the modality which each uses may differ).

Nest habitats of species may vary in the visual location cues they provide to be used while parent-offspring recognition bonds are being established. Species characteristics such as chick mobility, creche formation, and nest density also have to be considered. For the egg stage, factors such as nest site gestalt, egg coloration and nest density play a role. These factors support the argument that development of egg and chick recognition is a species characteristic. Choice trials, such as those using vocalization playback trials, can be used, to better estimate the time at which recognition occurs and demonstrate whether recognition development is truly a species characteristic determined by both genetic and environmental factors.

Recognition behavior by Forster's Terns nesting on islands in the Columbia River may have a great impact on their reproductive success. On the islands of the Columbia, nesting occurs in areas of relatively sparse vegetation and uniform sand/cobble substrate. Under these conditions, and with high nest densities, recognition behavior employing sensory modalities from either nest site, egg, or chick, or a combination thereof, should be selected for.

Forster's Terns normally nest in marsh habitat. Even here their nest sites tend to be close together, exhibiting their colonial nature (Be 70). In either nest habitat, Forster's Terns nest close to open water (Th 81 and Be 70). Selection pressures for the development of nest site recognition ability, however, would probably vary between the two nesting habitats. Marsh nests, because of their location on floating vegetation, muskrat houses, etc. (Mc 71), possibly provide more nest gestalt visual cues and less chances for mobility on the part of the

chicks. This would reduce the need for individual egg and chick recognition.

Throughout the remainder of this paper, the following conventions will be used. The term, parent-chick recognition, will represent parental recognition of its own chicks, while chick-parent recognition will represent the alternate possibility.

THE STUDY AREA

The study area is located in the lower Columbia Basin of southcentral Washington. Most research efforts were concentrated on islands located in the Hanford Reach of the Columbia River near Richland, Washington. Forster's Tern colonies here were located on Islands Nos. 18 and 19. Also included in the study area was a location in the northeast corner of the Department of Energy's Hanford Reservation, the Wahluke Slope Habitat Management Area, where a colony of Forster's Terns had been observed two years previously (R. E. Fitzner, pers. comm.). Figures 1 and 2 show the study area and colony locations.

The study area receives about sixteen centimeters of precipitation annually, falling mainly in the fall and winter months. Summers are hot and dry, the springs windy, and the winters generally mild with little snow and occasionally cold temperatures. Winds tend to be from the southwest (Ha 71).

Islands Nos. 18 and 19 consist mostly of cobble substrate (Fi 80). At low river levels they are approximately 37.2 and 50.9 hectares in size (De 81), respectively. The tern colonies used only a small portion of the total area. The major plant communities of the islands have been previously characterized (Ha 71, Fi 80, and De 81).

The tern colonies were located on the upstream ends of the islands just above the high water marks caused by fluctuating water levels from Priest Rapids Dam. During the high river flows of spring, Island No. 18 is often split into two islands. This condition possibly spurred the

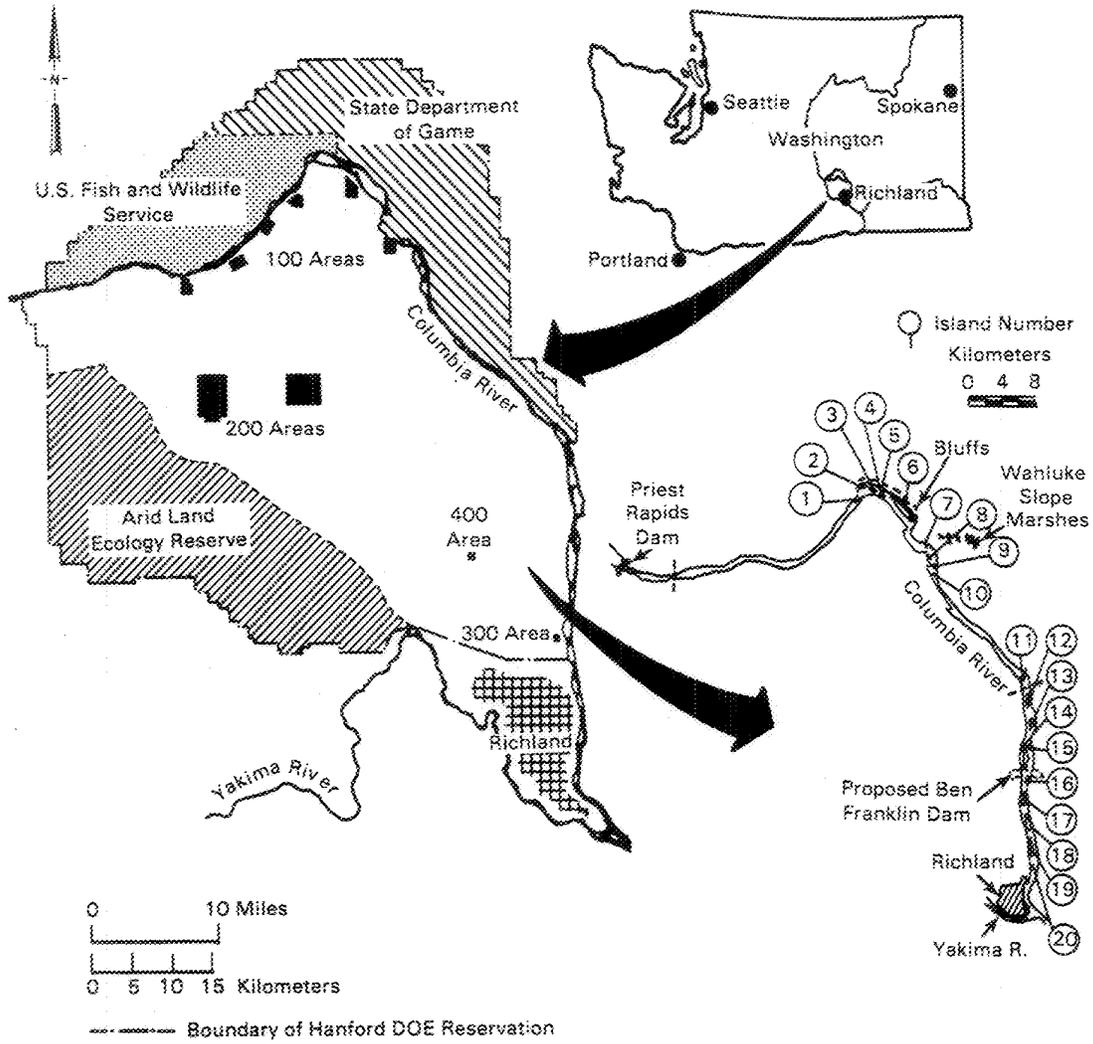


Figure 1. Hanford Reach of the Columbia River

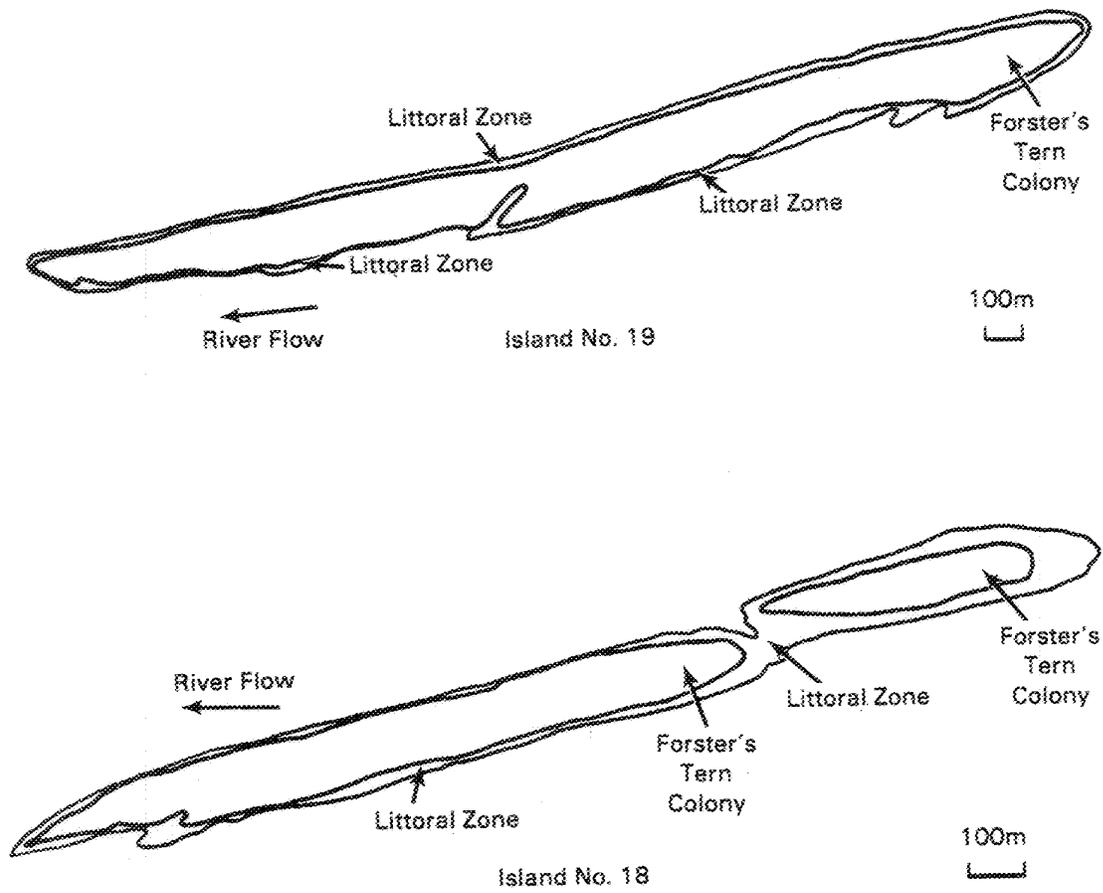


Figure 2. Islands No. 18 and 19 and Forster's Tern Colony Locations

development of a second Forster's Tern colony on Island No. 18 just downstream of the split location.

The vegetation characteristic of the colony location was similar for all three colonies. The dominant cover species were Absinthe (Artemisia absinthium), Northern Buckwheat (Eriogonum compositum), and Columbia River Grindelia (Grindelia columbiana). The colony site on Island No. 19 tended to be more sparsely vegetated. Small amounts of Lupine (Lupinus sp.) and Mulberry (Morus alba) were also present. Later in the breeding season, when the chicks left the colony proper, willow (Salix exigua) became important for cover as river levels became lower. During the high river levels earlier in the season, the willow was located in periodically wetted areas.

Numerous other colonial gull, heron, and tern species utilize the Hanford Reach islands for nesting habitat (Th 81). In addition, Canada Geese (Branta canadensis moffitti) nest on a number of the islands. Forster's Tern interaction occurs mostly with the gull species. The downstream Island No. 18 colony was flanked on its island side by a large mixed Ring-billed and California Gull colony. Island No. 20 was originally planned for use as a study site (a Forster's Tern colony was located on its upstream end the year before). Expansion of the Ring-billed and California Gull colonies there in 1985, however, possibly resulted in the terns abandoning the island due to loss of suitable nesting substrate.

The Wahluke Slope area used by the terns is a marsh habitat. This type of habitat is the normal nesting habitat for the Forster's Tern (Be 21 and Mc 71). For the Wahluke Slope marsh, the predominant plant

species were Bullrushes (Scirpus sp.). The marsh was established by and still receives most of its water from irrigation runoff associated with the Columbia Basin project.

METHODS AND MATERIALS

GENERAL

The study was conducted from May through July, 1985. Experimental manipulations were performed and most of the observational information was obtained from the tern colony on the upstream end of Island No. 18 (main study site). Colonies located on the lower section of Island No. 18 and on Island No. 19 were periodically surveyed for supportive data on productivity and reaction to human disturbance. In addition, the Wahluke Slope Habitat Management Area was also visited to assess the continued presence of Forster's Terns.

Experiments involved three categories of egg manipulations and one chick manipulation. Observational information included adult and chick call recordings, posture descriptions, reactions to disturbance, and various aspects of Forster's Tern behavioral ecology. Table 1 shows a schedule of visits made to each of the colony sites during the study. Dates missed at the main study site during active colony occupation were due mostly to either equipment problems, weather, or the need to reduce colony disturbance.

Table 1. Dates of Visits to Forster's Tern Colony Site Locations

Island No. 18 (Upstream Colony)	3-31, 5-1, 5-15 thru 5-18, 5-21 thru 5-24, 5-26 thru 6-3, 6-5, 6-8 thru 6-18, 6-20 and 6-21, 6-24, 6-26 thru 6-28, 7-10 and 7-27
Island No. 18 (Downstream Colony)	5-1, 5-15, 6-9, 6-21, 6-29 and 7-10
Island No. 19	5-1, 5-15, 6-9, 6-21, 6-29 and 7-10
Wahluke Slope	6-25

Observations at the main study site were made from an elevated, covered, hunter's blind (elevation approximately 1.5 meters). The colony was situated in a rough semi-circle around the blind with the closest nest being approximately 10 meters away. Observations were made either with the unaided eye, 7X35 binoculars, or a 20X - 40X spotting scope. Data were recorded for the most part on prepared data sheets. The field survey data were either recorded at the time of observation or dictated into a hand-held tape recorder and transcribed later. Approximately 145 hours were spent making observations from the blind during May and June. One hour was spent during July. Approximately 20 hours were spent conducting nest surveys at the main study site, generally in the morning, during the time of colony occupancy.

Numbered tongue depressors were placed in the ground within a meter of each nest to aid in nest identification. Following nest numbering, detailed records were kept on nest chronology as afforded by the almost daily visits. A map showing nest locations relative to the blind and other nests was also made to aid identification (Figure 3). According to their location and visibility from the blind, individual nests were categorized as for use as control nests, experimental nests, or undisturbed nests.

Egg and chick recorded data included: identification of the stage of hatching [i.e., early pip, pip, early ring, ring and emergence as described by McNicholl (Mc 83)], chick mobility away from the nest site and hiding behavior, clutch sizes, egg length and maximum diameter by vernier caliper on collected abandoned eggs, egg laying and hatching dates, hatching success, and chick mortality at the nest site. Data on

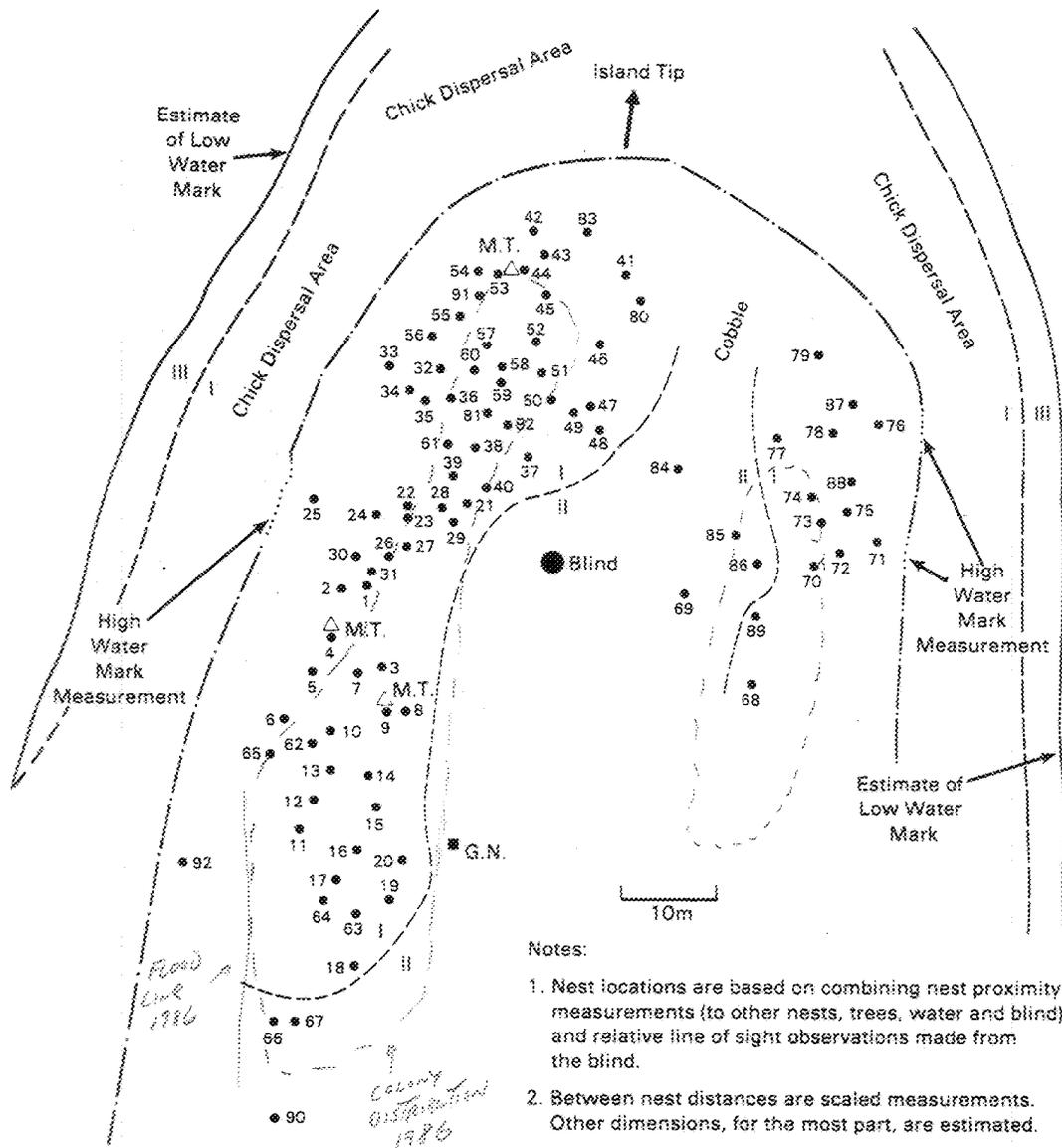


Figure 3. Relative Nest Locations at the Main Study Site on Island No. 18.

Nest Code Data

1	C, H	32	H	63	P
2	C, H	33	EG, H	64	C
3	A	34	EG, H	65	A
4	C, H	35	P	66	EG, H
5	C, ES, H	36	H	67	EG, H
6	A	37	H	68	A
7	C, H	38	P	69	P
8	P	39	H	70	EG, H
9	C, H	40	A	71	EG
10	H	41	A	72	EG, H
11	A	42	A	73	EG, H
12	C, H	43	A	74	EG, H
13	C, H	44	H	75	EG, H
14	A	45	H	76	H
15	C, H	46	EG, H	77	P
16	A	47	H	78	A
17	A	48	A	79	P
18	C, EG, H	49	H	80	EG, H
19	C, H	50	H	81	P
20	C, H	51	H	82	P
21	H	52	H	83	P
22	H	53	EG, H	84	H
23	P	54	EG, H	85	H
24	H	55	A	86	A
25	EG, H	56	EG, H	87	A
26	ES, H	57	EG, H	88	A
27	A	58	EC, H	89	A
28	H	59	ES, H	90	EG, H
29	EC, H	60	H	91	H
30	C, EG, H	61	H	92	H
31	P	62	H		

Legend

C	Primary control nests
EG	Experimental nest-egg
EC	Experimental nest-chick
ES	Experimental nest-sound recordings
H	Hatched at least one chick
A	Abandoned prior to the completion of incubation
P	Partial nest construction, no eggs layed
I	Absinthe Community
II	Northern Buckwheat Community
III	Willow Community
-----	Estimate of margin of vegetation communities
.....	High water mark measurements (from nests No. 25, 71 and 76)
-----	High water mark estimate
-----	Low water mark estimate
● 12	Forster's tern nest site and assigned number
■ G.N.	Ring-billed gull nest
△ M.T.	Mulberry tree

Figure 3. (Cont'd.)

average incubation time and other survey dependent data are not precise due to the non-continuous nature of the colony visits. When possible, chicks (n=60) were leg banded with number 3 size bands when they were one to three days post-hatch. The chick tarsus was able to accept a band at this stage without it slipping past the hallux.

Nest data taken at the conclusion of the study in late July included: measurements of nest cup diameter, depth, and total nest diameter; nest substrate; and proximities to shelter (vegetation of a significant height or bulk), water (river high water mark data actually recorded during peak spring river flows), blind and other nests (from edge of nest). Nest cup diameter was recorded as the distance across the crest of the cup. Cup depth was measured by placing a tongue depressor across the cup and measuring the perpendicular distance to the center point of the cup. Nest diameter was more subjective in that nests were not generally circular. Diameter was taken across what appeared to be the major axis of construction. The vegetation selected for measurement was similarly subjective as the investigator selected that plant appearing to represent a dominant physical landmark near the nest site.

EGG AND CHICK MANIPULATIONS

Manipulations to test parental recognition of eggs and chicks were performed in the early morning between 0530 and 0830 for the eggs and around 0900 for the chicks. These time frames were used to prevent disturbing the colony during the heat of the day. Manipulations involving exchanges were made between nests judged by the investigator

to be sufficiently visually isolated, either by other nests or by vegetation. This precluded adult Forster's Terns from returning to the wrong nest site without performing obvious searching behavior. Twelve nests were used as controls. Though they were not used for manipulations, they were disturbed during surveys to ensure handling by the investigator could be discounted as adversely affecting a Forster's Tern's behavior. Nests Nos. 18 and 30 were originally selected as control nests. However, because of a later reduction in nest availability for experiments, they were used for egg experiments and eliminated from the control group.

Egg manipulations involved: exchanging single eggs between nests containing at least two eggs each, exchanging whole three-egg clutches between nests, and altering egg marking patterns within a clutch with a black felt tip pen. For the egg experiments, eggs were exchanged that appeared to be most dissimilar in their ground coloration and markings, while the alterations involved adding scrawls, spots, and splotches to the egg markings. Only one chick alteration experiment (involving two different nests) was performed. Both chicks altered were two days post-hatch and were leg banded with bands colored with green enamel paint. This was intended to allow distinguishing the altered chick from its nest mate, but because of distance and the visibility of a chick's legs, it proved to be a poor identification technique. Both chicks were altered using a black felt tip marker; however, on the first chick the marker was a dry applicator and only the posterior of the bill (about the last two millimeters) was blackened. On the second chick a wet applicator was used. This allowed for spots to be added to the down of

the back and for the head down to be blackened. Bent (Be 21) and McNicholl (Mc 71) can be referenced for descriptions of Forster's Tern's natural egg and chick coloration.

Observations of nests to be manipulated were made for a day prior to the manipulation. These observations and those of the controls were made using a scan technique (Mi 75). Observations were made every 15 minutes and the adult tern's behavior categorized as to whether it was incubating the eggs (or brooding chicks), standing near or over the nest, feeding a chick, or absent from the nest vicinity. At least 20 observations were recorded prior to the manipulations. In most cases, each control was observed 20 times a day. The observations established the normal behavior of a breeding pair. Observation times varied, starting no earlier than 0700 and ending no later than 1430.

Following the egg exchanges, the nests were observed continuously for at least an hour and parental response observed for acceptance or rejection. After the eggs were returned to their original nest, observations were long enough to witness the parent's reacceptance of its own egg(s). The altered eggs were observed by scan technique for at least four days (for one nest this was only three days since on day three it had one chick hatch). Altered chick nests were observed continuously until a parental response towards the altered chick could be discerned and then frequently thereafter (including scan technique) on the day of alteration.

VOCALIZATION RECORDINGS AND PHOTOGRAPHS

Most initial sound recordings were made using a Uher 4200 Report

Stereo IC. For all chick calls and for a limited amount of adult tern calls, recordings were first made on a pocket size Sanyo cassette tape recorder held by the investigator and later transferred to the Uher. The need for this approach was due first to the weak intensity of chick calls. Secondly, the elicitation of the chick calls recorded and a particular adult call (i.e., attack call) were dependent upon disturbance by the investigator. Useful recordings of some chick call types were not obtained.

Recordings on the Uher were made using a fabricated directional microphone pointed at the nest to be monitored. The microphone arrangement consisted of a PVC pipe 15.4 centimeters (6 inches) in diameter and 42 centimeters long. A remote control microphone was inserted through one end and padded with foam rubber. The padding surrounded the rear of the microphone covering the full extent of the diameter of the pipe and provided attenuation of sound signals received opposite from the desired direction. The microphone was set approximately 25 centimeters away from the open end. The PVC pipe was placed on the ground six to nine meters away from the nest of interest. The distance away was constrained by the availability of close nest sites and keeping the length of microphone cord down to minimize line resistance. The pipe was painted brown and covered with burlap for camouflage. The recorder was kept in the blind. Recordings were obtained in monophonic at a tape speed of 19 cm/sec. A total of approximately fifteen and a half hours was spent monitoring different nests on five separate days. Monitoring consisted of observing the nest for behavioral activities and turning on the recorder when such

activities included vocalizations. Occasionally, terns flying and vocalizing overhead in the vicinity of the microphone were also recorded.

Quality of the recordings was greatly affected by background noise such as boat traffic, airplanes, and general colony noise. As a result, calls were later prioritized as to their clarity and ability to be assigned to an individual bird making a particular call. Nine different adult and four chick calls were initially identified by the investigator. One of the adult calls (fish call) was observed to function as an identification call. Repeated recordings were made of individual adult terns making the fish call as well as of different individuals making the call. The highest quality recordings for each type of call recorded were used to make sonagrams of 2.4 seconds in duration with a maximum frequency response of 8 kilocycles per second. A wide bandpass filter setting (bandwidth 300 cycles per second) was used. The spectrograph equipment used was a Sona-Gram, Sound Spectrograph 661A manufactured by the Kay Electric Company. The sonagrams were subjected to analysis to determine if the different calls could be differentiated by their sound profiles and if a case could be made for the fish call functioning as an identification call.

An attempt was made to correlate various calls with their associated postures and behaviors. When possible to supplement descriptions, photographs were taken from the blind of adult postures using a 35 mm SLR camera equipped with a 500 mm lens.

If available, the names used to identify a particular call or posture follow the nomenclature already used by other authors (Mc 71 and

Hu 68). Where a call or posture appeared to be newly identified in this study, the investigator assigned a name that appeared descriptive either in sound or in function.

RESULTS

EGG MANIPULATIONS

Data collected on control nests serve as a baseline for establishing the activity patterns of a normal breeding Forster's Tern pair. Table 2 summarizes the results for the egg stage, early pip and pipped stage, and pooled data from the two stages.

Table 2. Parental Activity Frequency During the Egg Stage (E),
Early Pip and Pipped Stage (Ep) and Pooled Data (Controls)

Stage ¹⁾		E	Ep	Pooled
No. nests		12	8	12
No. Tallies ²⁾		1875	245	2120
Incubating	- % ³⁾	98.0±1.9	98.5±2.3	97.9±1.9
Standing	- % ³⁾	0.6±1.1	0.0	0.6±1.1
Not in nest vicinity	- % ³⁾	1.4±0.9	1.5±2.3	1.5±0.9

1) Stages: E = eggs; Ep = early pip or pipped eggs. Data for the early ring and ring stage were not included due to the briefness of the stage, the small amount of data, and the possibility that the stronger "chick" stimulus may represent a turning point for parental behavior away from the pure incubation stage.

2) Surveys of parental activity frequencies were by scan technique (Mi 75), normally twenty times per day.

Table 2. (Cont.)

- 3) Each scan observation of a nest represented one datum point. The percentages (plus one standard deviation) are the mean percentage of individual nest percentages.

The data in Table 2 are comparable to that obtained for Ring-billed Gulls (MI 75) with the exception that in this study a category was added to account for the condition when neither parent was present at the nest site. This behavior was common for Forster's Terns and could be due to colony upflights as a reaction to some disturbance, the need to wet the breast feathers in the river to cool incubating eggs, or individual reaction to an intruder. Food was never observed being brought to the eggs, though numerous feedings of a mate on the nest were observed.

The slight increase in incubation frequency during the Ep stage indicates a possible trend for the incubating parent bird to "sit tighter" during the later stages of incubation. Table 2 data are useful for comparison with the premanipulation data of the experimental nests. This permits an assessment of the premanipulation behavior of the experimental nest to see if such behavior may have affected the experimental outcome. Though premanipulation sample size was small (20 - 25 tallies for most nests), the results indicated no obvious departures from the baseline: mean incubation frequency plus one standard deviation of 97.9 ± 3.3 percent (range 90.0 - 100 percent).

The approach described above also can be indicative of an abnormally behaving breeding pair. This is exemplified by data on nest

No. 17. Table 3 summarizes the scan observation results.

Table 3. Parental Activity of Nest No. 17 During the Egg Stage (E)¹

No. tallies		80
Incubating	%	37.5
Standing	%	2.5
Not in nest vicinity	%	60.0

1) The percentages are in percent of total scan tallies.

Over a five day observation period of adult terns in the vicinity of nest No. 17, occupancy at the nest dropped steadily until total nest abandonment occurred (one observation day in the middle was missed). During the period of occupancy, it appeared that an adult from nest No. 17 even incubated the wrong nest at times (previously abandoned nest No. 16).

Though experimental nests were not always observed by scan technique following the manipulations (all the altered egg nests were observed for three or four days), they were periodically observed to assess the status of their eggs or chicks. All nests used for egg experiments, with the exception of one, successfully hatched at least one chick. The adults on the unsuccessful nest were sitting on addled or infertile eggs, since they were observed to incubate for a minimum of 54 consecutive days (average incubation time is roughly 24 days; see Appendix Table 5).

Results from the egg exchanges/alterations are summarized in Table 4 (A, B, and C). Table 5 provides post manipulation scan observation data (parental activity frequencies) on the four nests where egg alterations were performed and in one nest, No. 30, where a whole clutch egg exchange was performed.

Following egg exchanges and alterations, the returning adults in all cases settled normally on the nest once they had alighted at the nest site (generally on the nest rim or close to it). In a few instances, adults circled in the vicinity of the nests for a few minutes prior to landing. Once they landed, settlement was immediate and normal; no hesitation was observed. The few slow returns to the nest were interpreted to be unique responses of individuals to a colony disturbance.

Half of the nests having egg exchanges were observed while a nest exchange between mates took place. Settlement by the new bird was without hesitation. Following the return of eggs to their original nests, all adults settled normally on their nests.

Nest manipulations were performed during the middle and later phases of the incubation stage. The majority of the exchanges were performed during late incubation. Testing can reasonably be expected to have covered the time period during which the onset of egg recognition behavior would have occurred.

CHICK MANIPULATIONS

Parental activity frequency data for the chick stage were not nearly as extensive nor as accurate as data for the egg stage. For

Table 4. Egg Manipulation Results.

A. Single Egg Exchange									
Nest No.	25	34	46	53	57	72	75	80	Totals
Parent response to:									
Replacement egg	+ ¹⁾	+	+	+	+	+	+	+	8+; 0-
Own egg	+	+	+	+	+	+	+	+	8+; 0-
Returned egg	+	+	+	+	+	+	+	+	8+; 0-
Nest exchange observed while exchanged egg present	Y	N	Y	?	Y	Y	N	Y	5Y;2N;1?
Exchange date in relation to hatching date of first chick from nest (difference in days)	9or10 ¹⁾	7-9	11-13	5	15	6	7or8	2	NA
B. Whole Clutch Egg Exchange									
Nest No.	30	33	54	56	70	71	73	74	Totals
Parent response to:									
Replacement clutch	+	+	+	+	+	+	+	+	8+;0-
Returned eggs	+	+	+	+	+	+	+	+	8+;0-
Nest exchange observed while exchanged clutch present	N	N	N	Y	Y	N	N	Y	3Y;5N
Exchange date in relation to hatching date of first chick from nest (difference in days)	8or9	7-9	7	5or6	9-12	*	2	5	NA

* None hatched.

Table 4. (Cont.)

C. Whole Clutch Egg Alterations					
Nest No.	18	66	67	90	Totals
Parent response to:					
Altered Eggs	+	+	+	+	4+;0-
Alteration date in relation to hatching date of first chick from nest (difference in days)	6-8	9	4or5	2	NA

1) Symbols: + = accepted (incubated); - = rejected; Y = Yes; N = No; ? = could not confirm.

2) In some cases the exact hatching date of a chick was missed, therefore an estimated range of days is given. Based upon an average incubation period of 24 days (see Appendix) and three stages of incubation, a difference in days of one through eight corresponds to late incubation, 9-16 to middle incubation; and greater than 17 to early incubation.

Table 5. Post Manipulation Parental Activity Frequencies (Pooled E and Ep data) ¹⁾

Nest No.	18	30	66	67	90 ²⁾
No. tallies	75	140	75	75	40
Incubating - %	98.7	98.6	98.7	97.3	97.5
Standing - %	0.0	0.7	0.0	0.0	0.0
Not in nest vicinity - %	1.3	0.7	1.3	2.7	2.5

1) The percentages are in percent of total scan tallies.

2) Nest No. 90 was observed to have a chick present prior to the third day of post-manipulation observations.

feeding events were difficult to observe. A parent frequently brought food (only fish were observed) back to the nest but appeared to fail to feed the chick. Though a visual exchange between parent and chick was not always possible, vocal exchanges could still occur. The brooding parent, however, remained atop the chick; the chick perhaps being too weak during the first day following hatching to push itself out from beneath its parent. The parent returning with the fish, after not finding a recipient for its catch, often ate the fish itself or fed it to its brooding mate. It is possible, that during the first day of its post-hatch existence, a chick uses the remains of its yolk reserve and requires less feedings.

Nest cover sometimes presented a visual barrier, making it difficult to judge the correct activity of the parental terns. Also, nests were not standardized (Mi 75) and there was often a combination of chicks (two or three) of different ages in the nest; thus, data could not be properly assigned to a particular day after hatching. Additionally, some nests underwent a reversal of conditions where on one day it had a chick, the next none (due to the chicks death), and then a new chick on the following day. No attempt was made to see how these situations affected parental activity frequencies. Finally, a number of the nests used to observe chick data were close to the blind. Some of the adults at these nests appeared to lead their broods away from the nest site prematurely, possibly due to the presence of the investigator. Their prior behavior may have also been affected by close proximity to the blind.

For these reasons the scan observation data for the chick stage is

not used in making comparisons of parental behavior towards altered chicks. A limited amount of scan data for the chick stage is presented in the Appendix (Appendix Table 6). Because little feeding activity was observed, the Appendix also contains feeding frequency data based upon continuous observations of a nest (Appendix Table 7).

The chick experimental data presented here are limited to the alteration of two, two-day post-hatch chicks. Though the original experimental design was similar to that for eggs, involving single and whole brood exchanges and alterations at different days post-hatch, almost all of these experiments were curtailed. Most of the chick manipulation experiments were eliminated partly because of: (1) smaller colony size than anticipated (fewer than sixty nests hatched chicks); (2) somewhat asynchronous hatching (hatchings occurred over roughly a month); (3) poor nest visibility for observing most chicks; (4) colder than usual weather during the time used for performing manipulations (cold weather is not a problem for the eggs, but chicks one day old can't thermoregulate adequately); (5) more mobile chicks than expected; and (6) increased agitation by the colony to the presence of the blind and the investigator during colony surveys. Trying to force additional chick manipulations may have adversely affected the breeding success of the colony.

Results from the chick alteration experiments are summarized in Table 6. In both experiments the alteration of the chick did not appear to affect the parental response towards it. The limited altering of the chick using the dry applicator, nest No. 29, makes interpretation of the results of that experiment tenuous.

Table 6. Single Chick Manipulation Results - Chicks Altered at Two Days Post-Hatch

Nest No.	29	58
Parent response to:		
Altered chick	+ ¹⁾	+
Home chick	+ ²⁾	+ ³⁾
Chick behavior:		
Altered chick	c	u
Home chick	u	u/c
Chick color-banded	a	a
Territorial Situation	p	w
Applicator type	Dry	Wet

- 1) Symbols: + = accepted (brooded); - = rejected; c = crouched; u = upright posture; a = altered chick; h = home chick; p = open (nests greater than 2 m apart); w = crowded (nests less than 2 m apart).
- 2) Following the disturbance to the nest having the alteration, the unaltered chick (four days post-hatch) did not return to the nest site for at least 40 minutes. The altered chick stayed in the nest after alteration.
- 3) Following the disturbance to the nest having the alteration, the unaltered chick (three days post-hatch) didn't return to the nest for at least one hour and 45 minutes. Upon its return, the parent appeared to come off the nest to peck it once (appeared to be calling to it previously); whereupon the chick responded by crouching. After the parent ignored it, the chick got up and entered the nest. Once there, it was brooded along with the altered two day post-hatch chick who had returned to the nest site immediately following the disturbance.

CALLS AND POSTURES

During the course of the manipulation experiments, data were collected as opportunity arose on adult and chick calls and postures. These data were primarily subjective. Once the chick manipulation experiments were curtailed, it became possible to make some quantitative measurements of various adult and chick calls using recording instrumentation. Photographs were also obtained to document postures.

The information available from the recordings was affected to a great degree by: (1) the high background noise, (2) the distance of the microphone away from the subject, and (3) the inability to assign repeated calls to a particular individual (adults were not marked). Additionally, interpretation of the call sonagrams was made difficult by the lack of linearity in the frequency scale on the calibration graph and the interference caused when a combination of calls was given at the same time. It was not possible to photographically document all the various postures due either to distance or the posture not occurring during photographing sessions.

Table 7 provides qualitative data on the nine proposed adult Forster's Tern calls covering a description of the call characteristics, the situation in which the call is given, the associated posture if any, and proposed functions for each call. Table 8A provides quantitative information on adult calls, except the fish call and pair bond call. Table 8B provides the quantitative fish call data including data that can be used to aid establishing the fish call as an individual identification call. Table 9 provides information on chick (and juvenile) calls. Recordings were made of all nine adult calls and only

Table 7. Qualitative Data on Adult Calls

Call	Description in Relative Terms	Situation	Associated Posture	Function
Attack	Piercing call; long duration; similar to protest call in spectrum; difference in sound to the ear could be due to doppler effect, since the tern gives the call as it passes through the bottom of the arc of a dive.	Given: At the low point of a pass over a human intruder's head.	None Observed	High intensity aggression signal; frighten inter-specific intruder.
Protest	Raspy, nasally sounding; long duration; high frequency peak, broad band.	Given: At the approach of an intruder (except gulls); when colony or an individual is disturbed (in flight or on ground).	Protest	Low intensity; aggression signal; warn intruder, interspecific or intraspecific; alarm call following disturbance.
Fish	Medium to long duration; composed of two segments, a fundamental segment (sometimes composed of two voices) and a segment composed of vertical bars of wider band width; relatively low frequency (lower voice); first segment given with a steady or modulated decreasing frequency (sometimes the scream call is added at the end of the call).	Given: When approaching the nest with food (fish); when leading chicks from or to the nest (often without food); during courtship flights when one of the pair is carrying a fish (giving call) and the other is chasing after.	None Observed	Approach/identification call; leading chicks; food bearing call.

Table 7. (Cont.)

Call	Description in Relative Terms	Situation	Associated Posture		Function
			Solicitation	Pair Bond	
Begging	High frequency; short duration, given in rapid succession; could show rise and fall in frequency in the call or just a substantial dropoff at the end.	Given: When begging for food from mate (chick call similar); as a reaction to gulls; when soliciting copulation (female); as a reaction to general disturbance.	Solicitation		Food begging; mobbing call; warning call; copulation solicitation; higher intensity distress call.
Pair Bond	Soft sounding; twangy; many call components (often masked by other calls).	Given: Following arrival at the nest with mate present (given immediately after landing); in vacuum on the nest; when meeting own chicks or mate; during courtship including in flight.	Pair Bond		Pair-bonding (lower agonistic tendencies after rejoining mate following separation; also after rejoining chicks).
Scream	Medium frequency with perhaps a slight drop-off at the end; short to medium duration, given in rapid succession (combined with fish call at times and sometimes by itself).	Given: During agonistic encounters (approach of an intruder); as a part of the fish call.	Aggression		High intensity aggression signal, intraspecific; warning call.
Click	Short duration; click sound; given in rapid succession (combined mostly with the begging call).	Given: When leaving the nest; in conjunction with the begging call for chasing gulls; immediately following the fish call; during agonistic encounters.	None Observed		Interspecific high intensity aggression signal; underway signal.

Table 7. (Cont.)

Call	Description in Relative Terms	Situation	Associated Posture	Function
Chirp	Soft, short duration call; long silences in between calls.	Given: When leaving the nest; during courtship (by male in response to female); after landing at a nest without the occupant; as part of the calling to chicks.	When used during courtship displays the head and bill are pointed downward as in the pair bond posture.	Pair bonding with mate and chicks; underway call.
Trill	Medium duration; relatively low frequency that decreases through most of the call; soft, staccato (possibly a variation on the fish call?)	Given: When approaching the nest without food, with or without the mate present.	None Observed	Approach/identification call; call to chicks.

Table 8A. Quantitative Data on Adult Calls Excluding the Fish Call (Ranges)¹⁾

Call	Sample Size	Duration (secs)	Silence Period Between Similar Calls (secs)	Peak Freq. Attained (kilocycles per second)	Band Width at Peak Freq. (kilocycles per second)	Freq. Drop from Peak (kilocycles per second)	No. of Vertical Bars in Call/2 Duration (secs)
Attack	2	0.59-0.61		5.2-5.3	1.5-3.0		
Protest	3	0.18-0.53		4.9-6.5	2.6-4.3		
Begging	5	0.03-0.08	0.04-0.18	4.9-5.2 ^{3,4)}	0.5-0.6	1.4-2.2	
Scream	4	0.08-0.19	0.03-0.08	3.8-4.6	0.7-2.5		
Click	2	0.03-0.06	5)	5.2-5.3	0.6		
Chirp	2	0.02	0.24-0.57	3.5-3.8 ³⁾	1.0		
Trill	2	0.18-0.27	<0.01	3.5-4.2	0.6-0.7		8-15/0.01-0.02

- 1) Because of interference from other calls and background noise, and the partial nature of the sonograms, quantitative information from sonograms of the pair bond call were not obtained.
- 2) The sonogram of the trill call is divided into discrete vertical bars of changing peak frequency but fairly uniform duration. The silence periods are small compared to the duration of the bars, however, the call is heard and pictured on the sonogram as being discontinuous (staccato).
- 3) Fundamentals for the begging and chirp calls were at times hard to discern. Ranges are based upon comparison of calls within a call type and choosing the most likely location of the fundamental.
- 4) The location of the peak showed some variability, occurring in the first half or at the midpoint of the call.
- 5) Duration of the click call was hard to discern making determination of the silence period difficult; however, the call has a repeat cycle duration of 0.08-0.11 seconds.

Table 88. Quantitative Data on the Adult Fish Call (Ranges)¹⁾

Segment/Voice	Duration ²⁾ (secs)	Peak Freq. Attained (kilocycles per second)	Band Width at Peak Freq. (kilocycles per second)	Modulation Period of Fundamental (secs)	Number of Vertical Bars ³⁾
Fundamental:					
Lower voice	0.11 - 0.25	3.5 - 4.3	0.5 - 1.1	0.10 - 0.22	
Upper voice ⁴⁾	0.19 - 0.25	4.8	0.6 - 0.9	0.10 - 0.16	
Vertical Bar	0.06 - 0.24	3.3 - 4.0	1.3 - 2.0		5-24

1) Based on a sample size of eleven calls.

2) Total duration of the call, combining the fundamental and vertical bar segments, ranged from 0.21 seconds to 0.43 seconds. When given in combination with the scream call, the silence period between the end of the fish call and the beginning of the first scream ranged from 0.07 seconds to 0.09 seconds.

3) The vertical bars are not as discrete as in the trill call. They are similar in appearance to segments of the Sandwich tern fish call as depicted in Hutchison, et al. (Hu 68).

4) Data for the upper voice is taken from only two fish calls (possibly the same individual). Other calls either did not show the second voice or if present it was not distinguishable enough to provide useful quantitative information. The occurrence of two non-harmonic voices may be due to the voices being produced by the opposite sides of the bird's syrinx (St 83).

Table 9. Chick Call Data

Call	Duration (secs)	Silence Period Between Similar Calls (secs)	Peak Freq. Attained (kilocycles per second)	Bandwidth At Peak Freq. (kilocycles per second)	Description	Situation/Function
Cheep						
					Short duration; soft, high frequency sound.	General discomfort call by chicks a few days old; also heard while still in the egg during <i>Ep</i> stage.
Scream ¹⁾	0-24-0.63	0.13-0.32	5.1-5.3	1.8-2.5	Shrill (piercing); high frequency; medium to long duration.	Older chick high intensity alarm call given when disturbed by an intruder (especially when handled).
Begging						
					Similar to adult but weaker.	Food begging as in the adult; perhaps also serves as a chick identification call since it is given in response to the adult fish call.
Protest						
					Similar to adult but peak frequency sounds higher.	Call situation/function similar to adult's, given by flying juveniles.

1) Based on a sample size of four. Two calls were originally considered to be possibly classified as a cheep, but their characteristics were mostly indistinguishable from the scream. One of the scream calls is of a thirteen day old banded chick. Duration and intensity may actually be the only differences between the two calls.

Table 10. Adult Posture Descriptions

Posture	Description
Protest	When standing: body straight; bill straight and open wide; wings raised and spread. When sitting on nest: wings can also be raised.
Solicitation	When off the nest: body horizontal, including tail and often head; bill open; facing conspecific; head can be raised slightly; back swayed.
Pair Bond	Body low; head and bill pointed downward and averted from conspecific; the carpals may be held out slightly when the bird just landed.
Aggression	When standing: wings (carpals) raised; body erect, bill open; head pointed vertical. Wings not raised when sitting on the nest.

one of the chick calls. Table 10 provides descriptions of the various adult postures.

Figure 4, A through D, provides representative sonagrams of the adult fish call. In A, the fish call is shown with the accompanying scream calls. The fish call in A also includes the modulated lower and upper voices. The call in B is hypothesized to be from the same individual (because the calls were recorded at different times and the birds were unmarked, this cannot be confirmed). The calls in C and D are from a different adult (C and D are hypothesized to be the same individual) that show no modulation in the fundamental nor two separate voices.

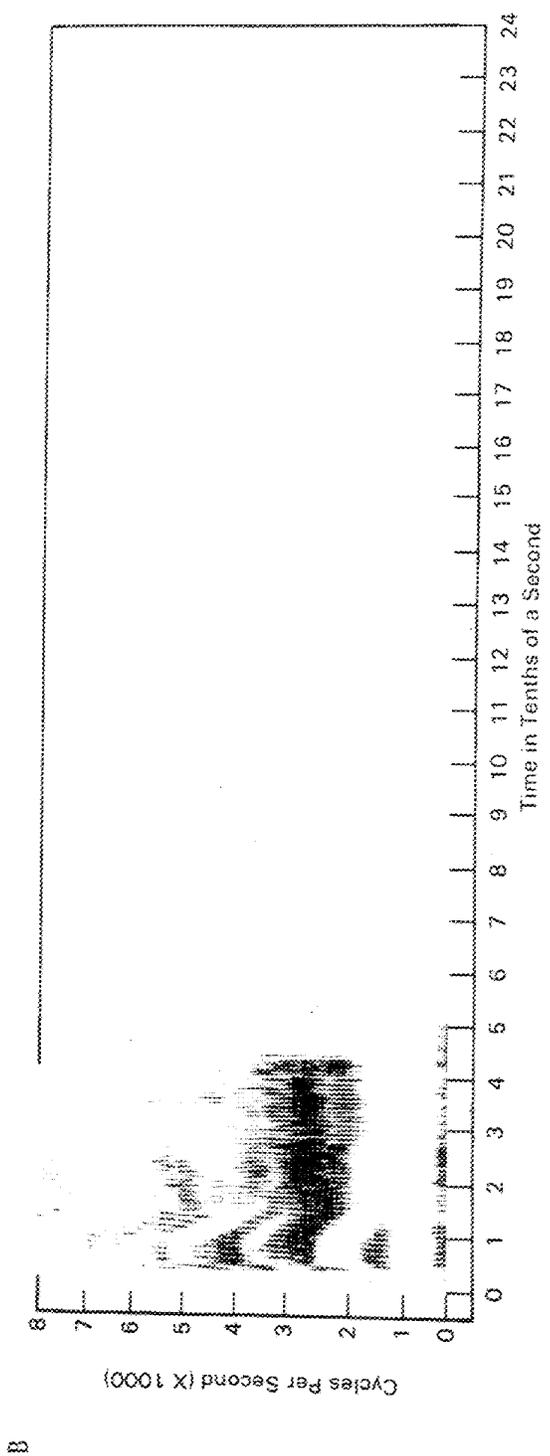
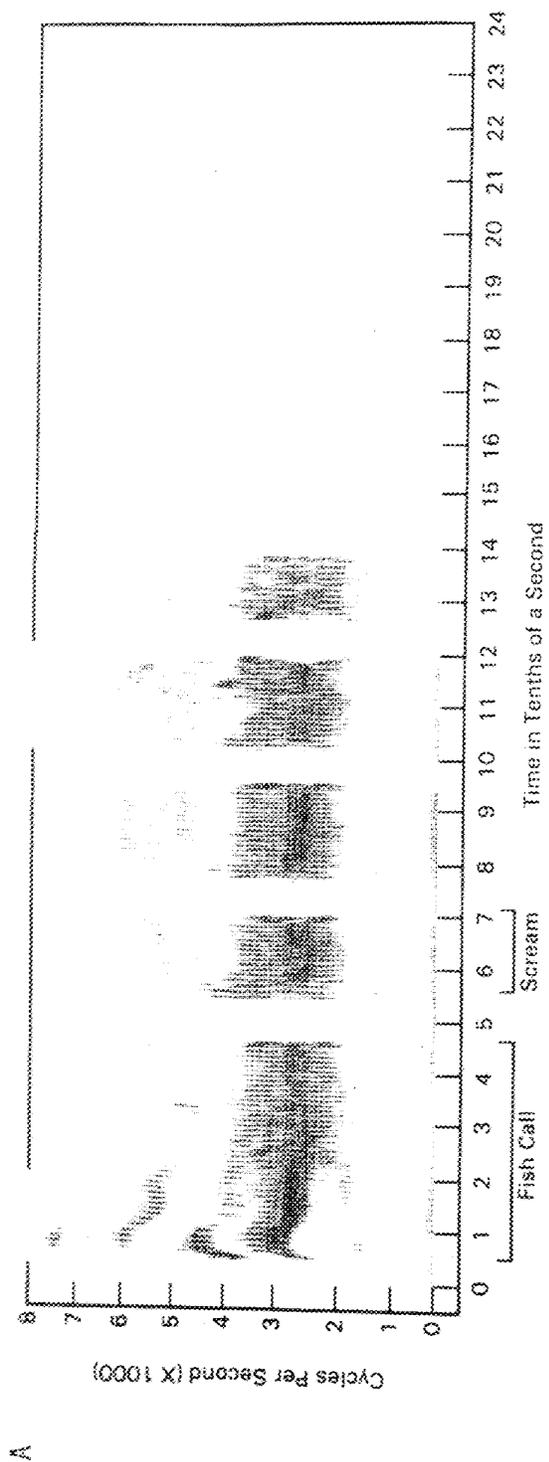


Figure 4. Adult Fish Call Sonagrams

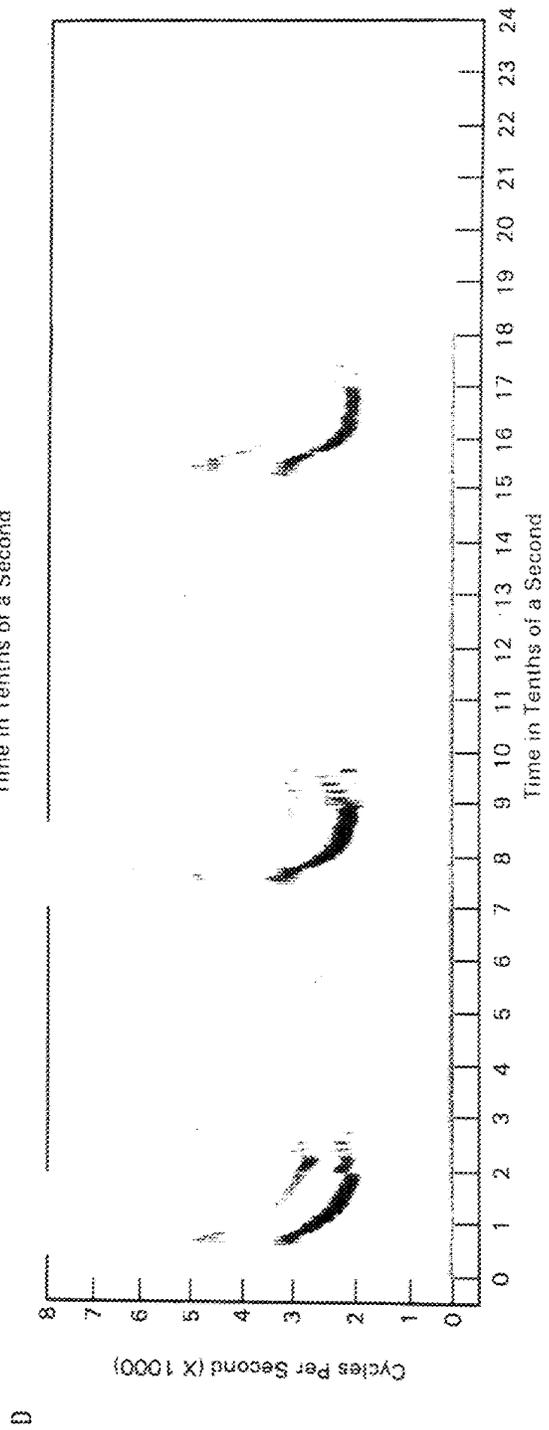
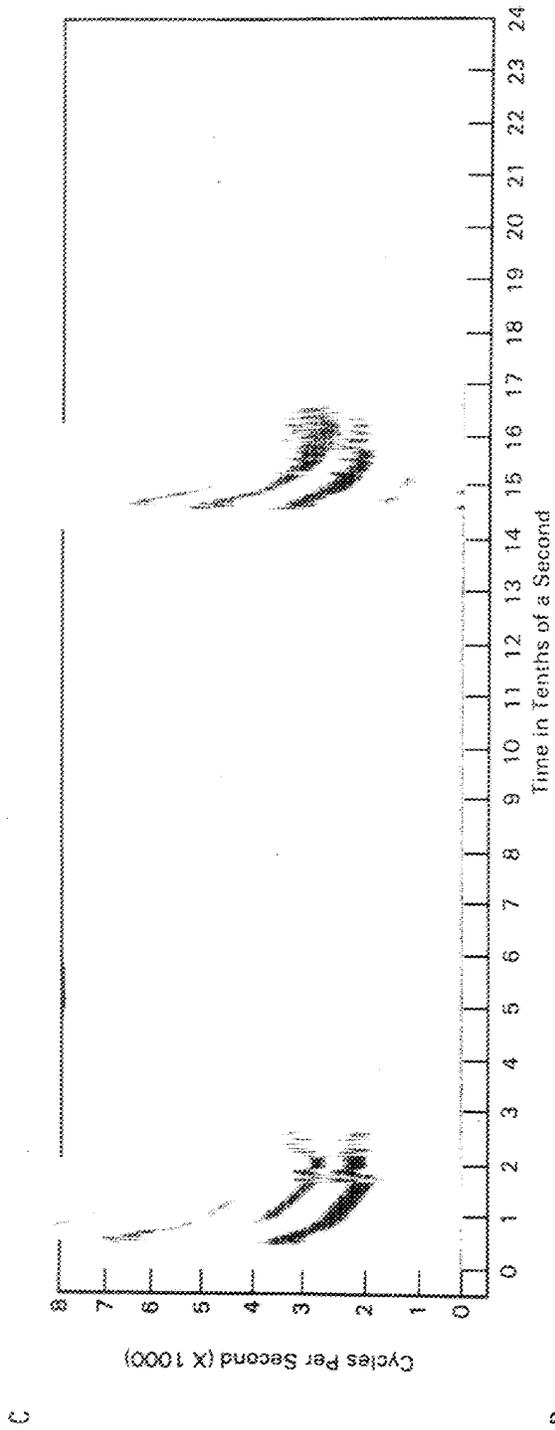


Figure 4. (Cont'd)

Figure 5 provides representative sonagrams of the adult protest call, trill call, begging calls (with clicks in one instance and the attack call in another), a partial pair bond call (with the fish call of possibly the mate of the individual in Figure 4, A and B), and chirp (A through F, respectively). Figure 6 shows a sonagram of a chick scream. Photographs of two postures were obtained, the pair bond and solicitation. These are provided in Figures 7 and 8, respectively.

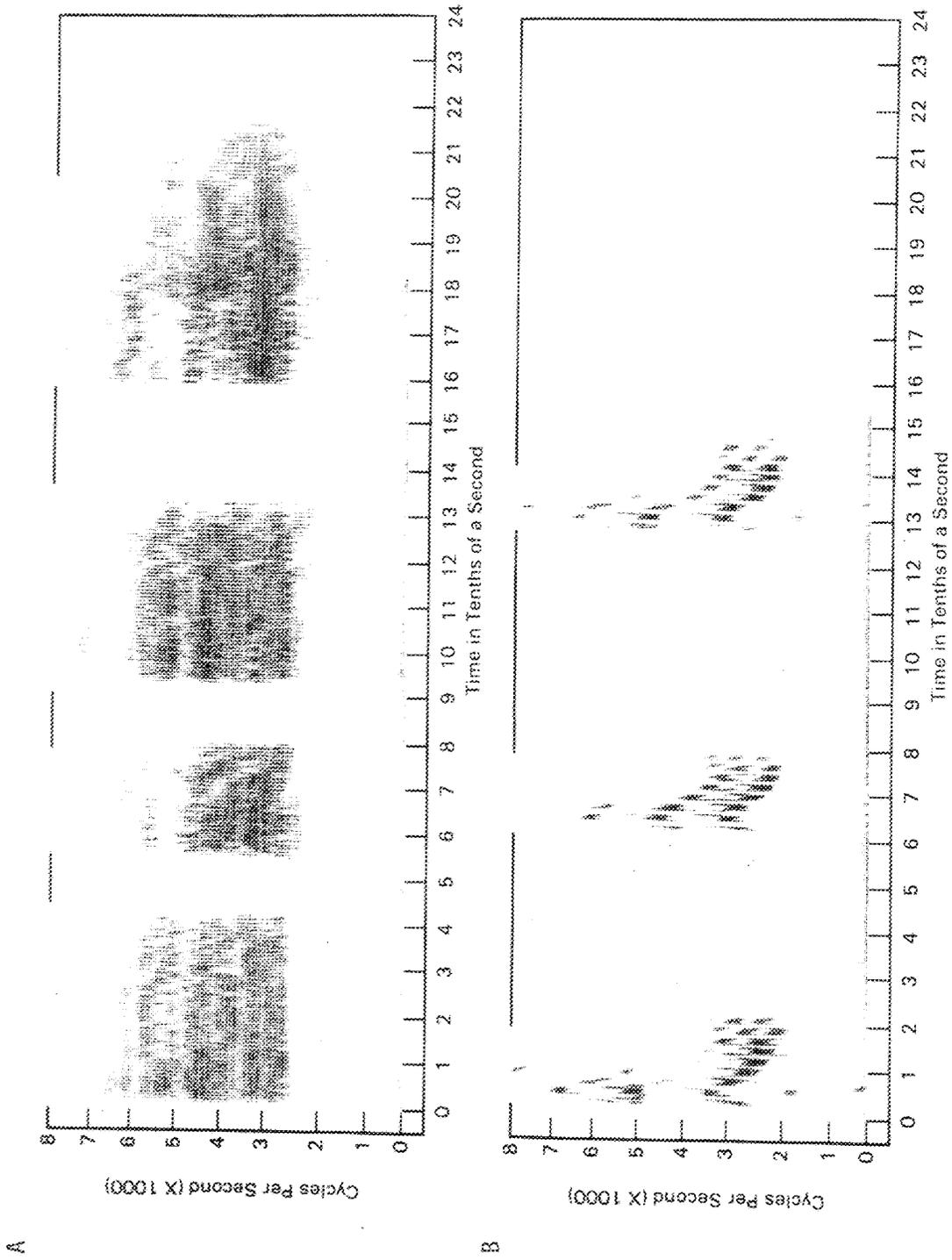


Figure 5. Other Adult Call Sonograms

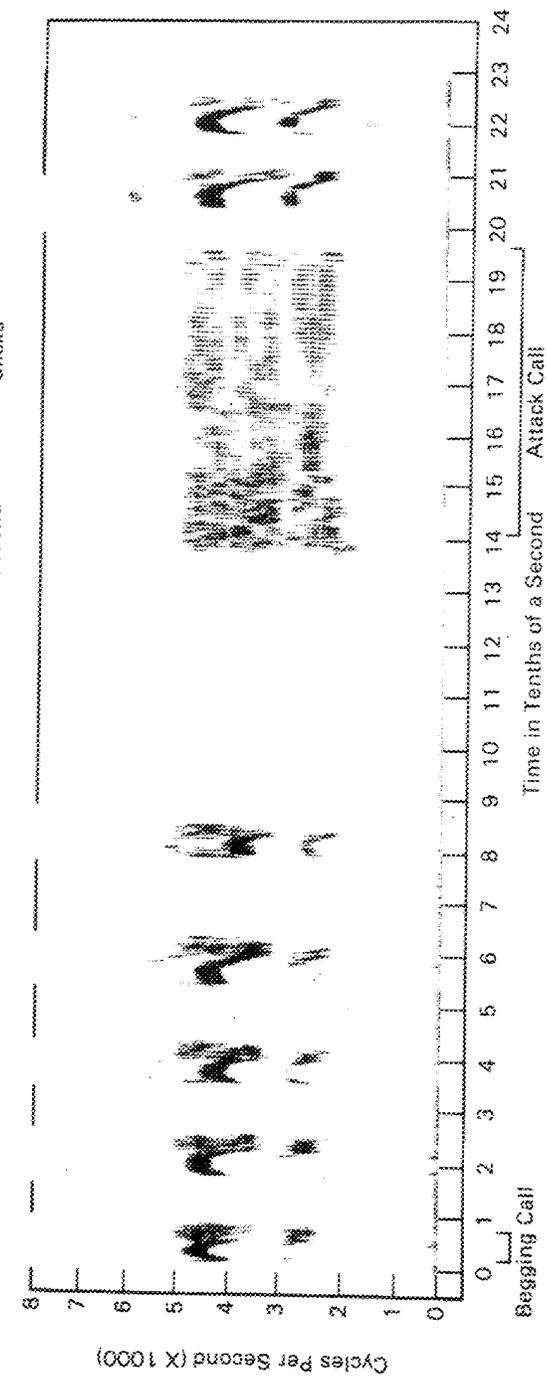
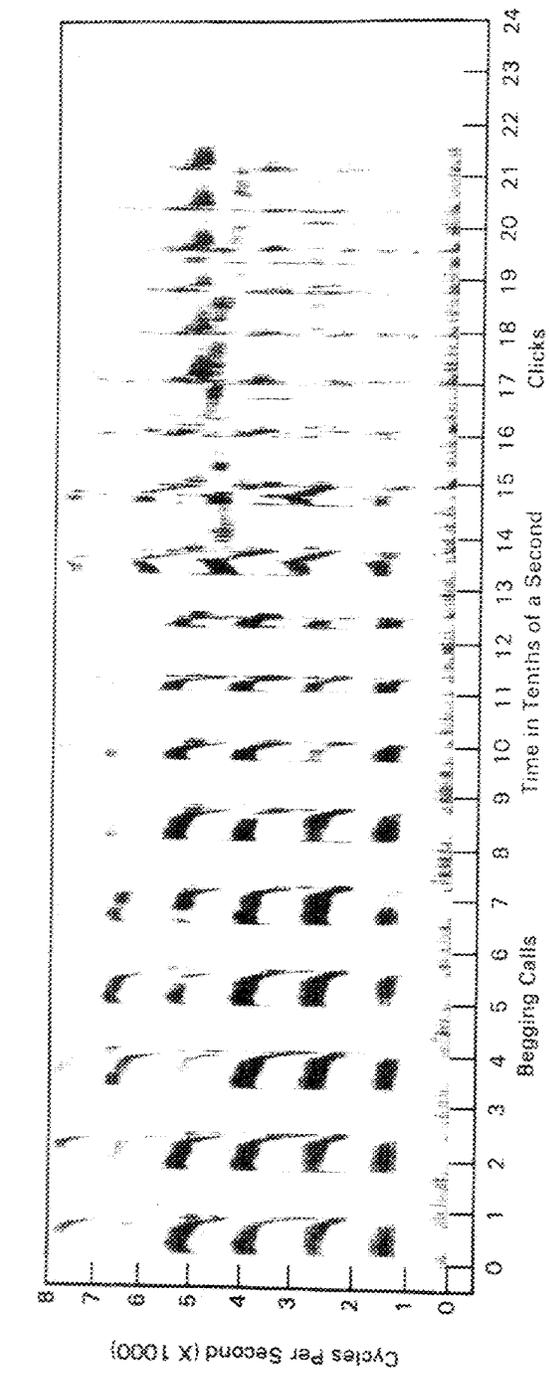


Figure 5. (Cont'd)

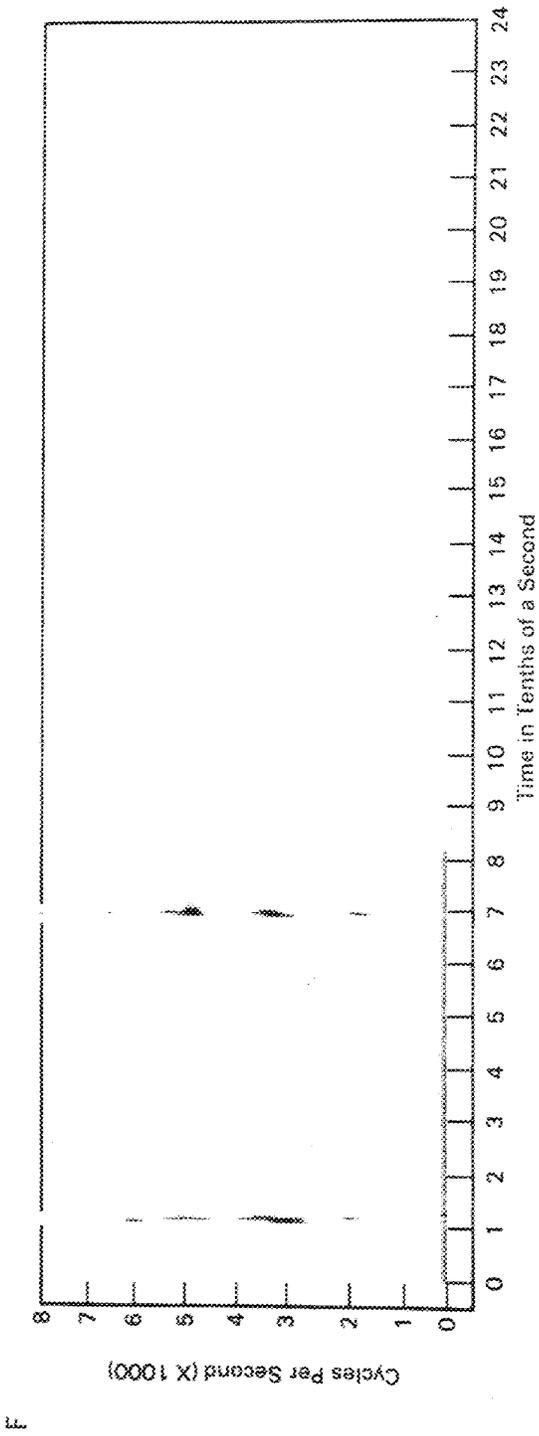
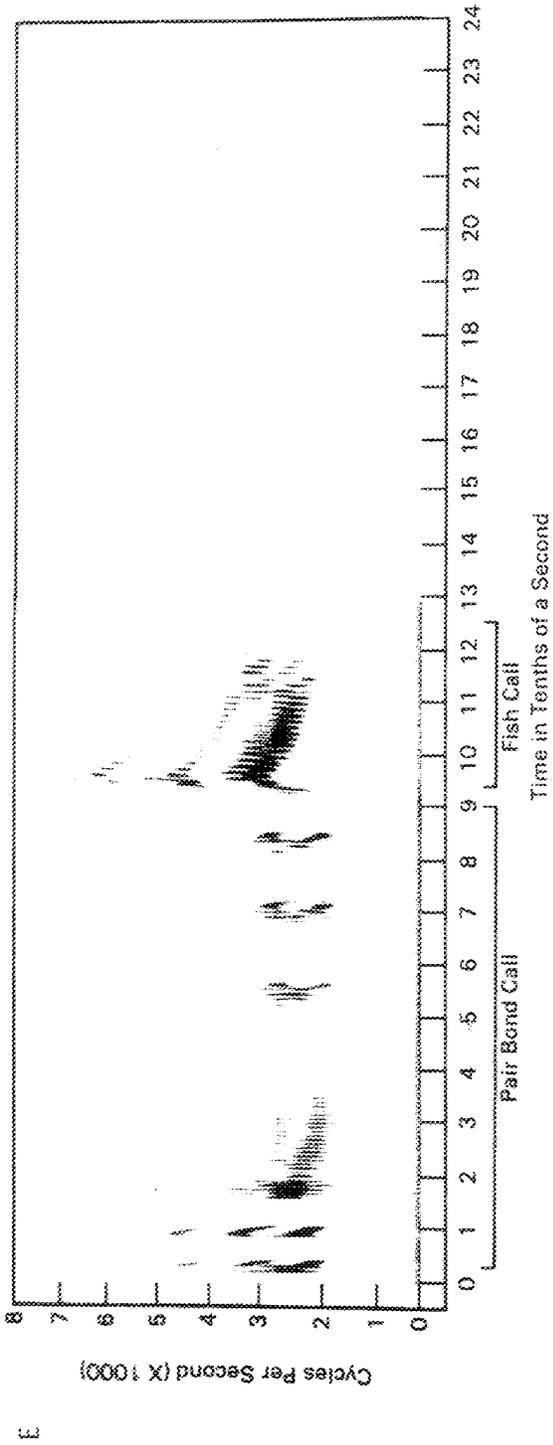


Figure 5. (Cont'd)

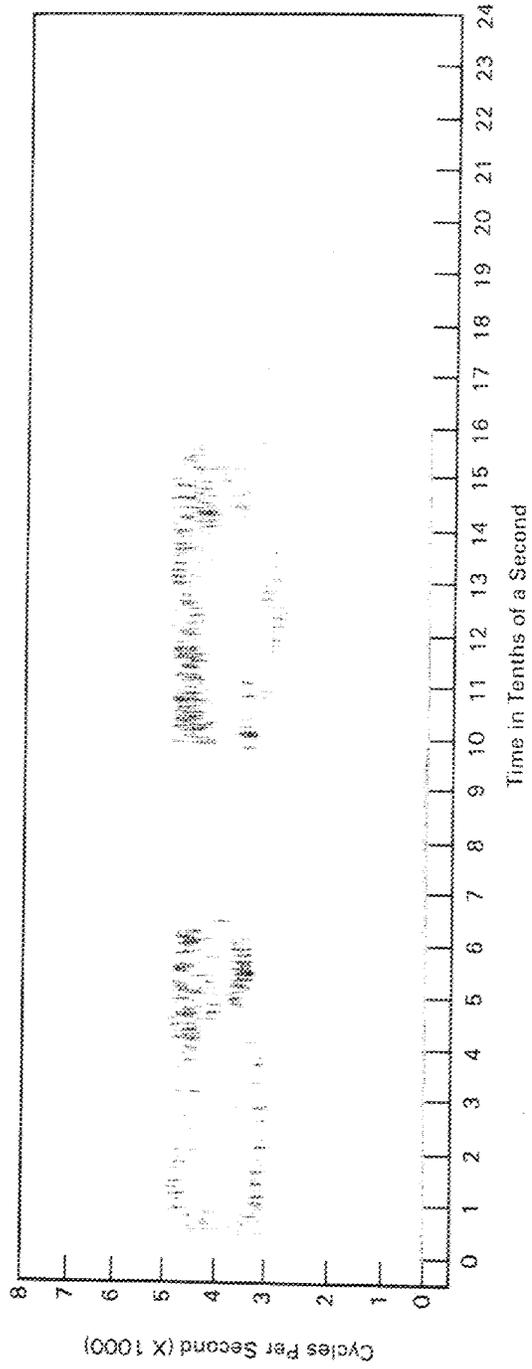


Figure 6. Chick Scream Sonagram

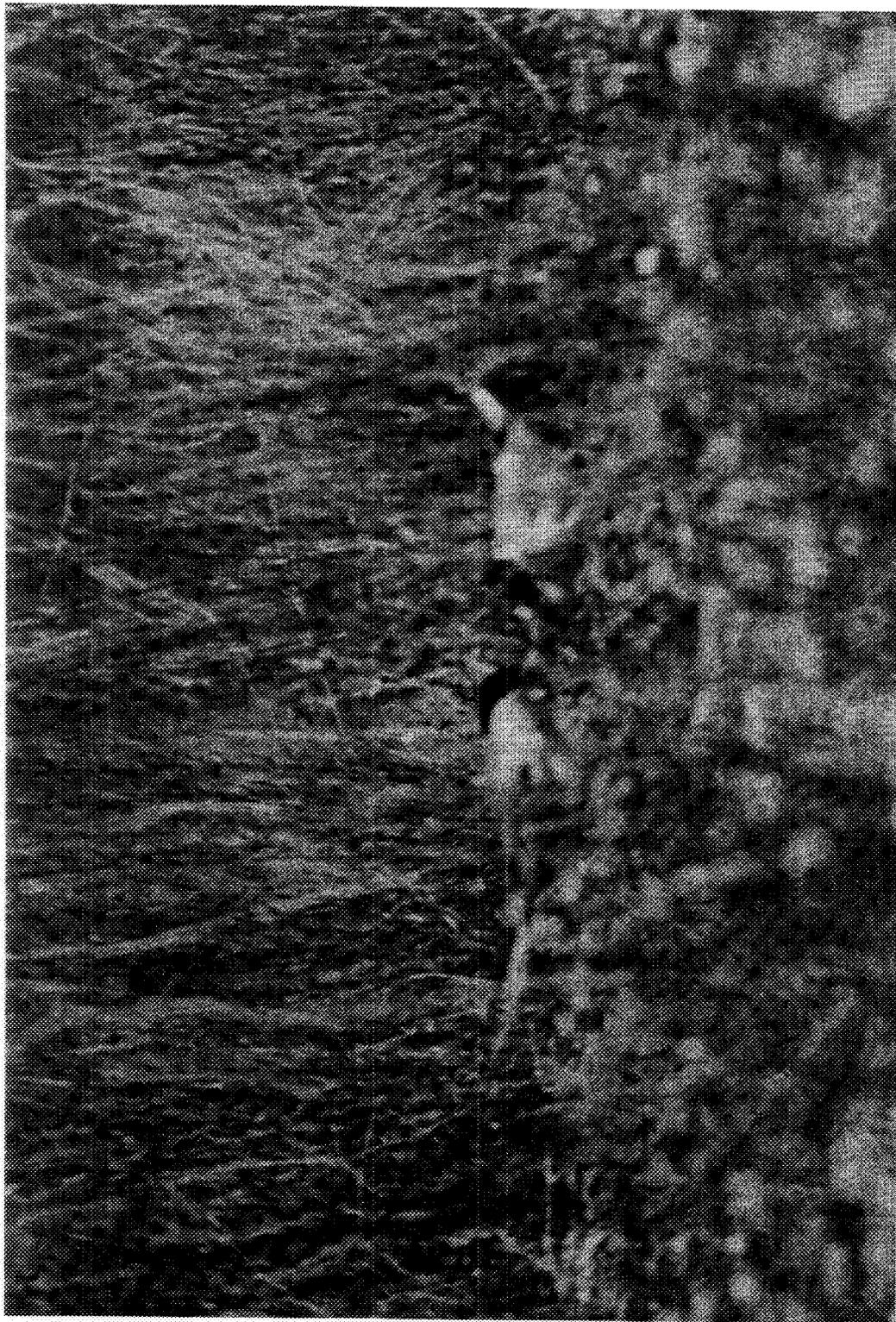


Figure 7. Adult Pair Bond Posture (Shown by Bird on Left)



Figure 8. Adult Solicitation Posture (Shown by Bird on Left)

BEHAVIORAL ECOLOGY - ASPECTS AFFECTING DISTURBANCE REACTIONS

A species response to disturbance is highly complex. The effect on productivity success is dependent upon a number of factors.

Breeding Chronology

Several of the islands on the Hanford Reach are in the McNary National Wildlife Refuge and fall under the jurisdiction of the United States Department of the Interior, Bureau of Fisheries and Wildlife, and are controlled access areas. The public is restricted from the islands between February 1 and June 30 of each year to provide undisturbed waterfowl nesting areas. Ducks and geese complete their nesting cycle within the above time frame (i.e., the young are capable, and do leave the islands with the adults). Islands of the Hanford Reach also provide nesting sites for large colonies of Ring-billed Gulls, California Gulls, and Forster's Terns (Th 81). The nesting chronology of these birds results in chick fledging occurring throughout the summer (Th 81); though limited data from this study for the Forster's Tern indicates fledging should have been completed by the end of July. Figure 9 shows the breeding chronology for Forster's Terns at the main study site (upstream end of Island No. 18).

The date(s) of first arrival were provided by R. E. Fitzner (pers. comm.). The date of commencement of egg laying and incubation is based upon the start of hatching minus the average incubation period of 24 days (see Appendix Table 5). The end of egg laying and the beginning and end of chick hatching are accurate within a day. All young had left their original nest site by June 28. The first confirmed observation

of a fledging chick was also on June 28. From this, fledging is estimated to take place four to five weeks after hatching. Thus, the completion of fledging for this colony occurs near the end of July, as indicated by the dashed line in Figure 9.

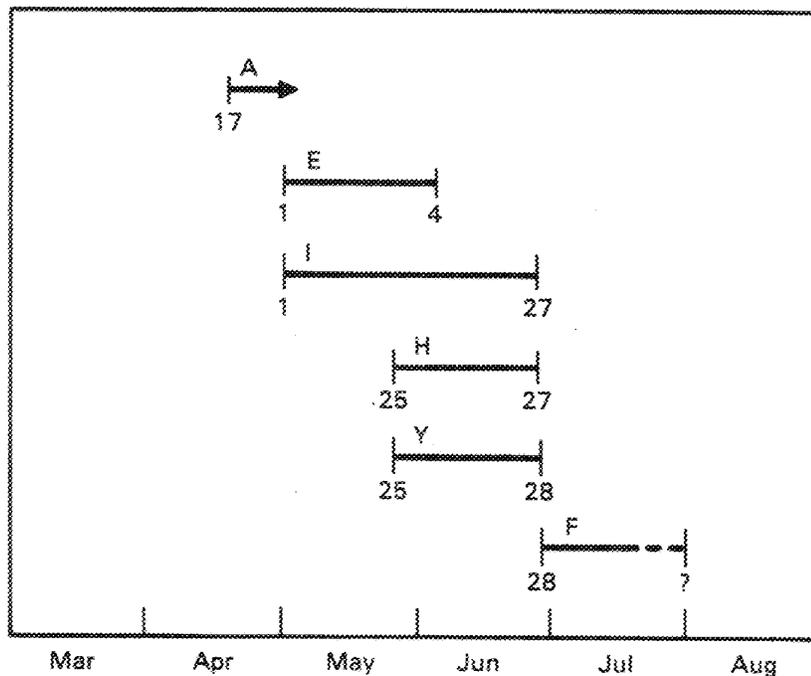


Figure 9. Breeding chronology at the main study site on Island No. 18. A = arrival at colony; E = egg laying; F = fledging; H = hatching; I = incubation; Y = Young in colony (young left original nest at an average age of four days; thereafter, until fledging, they were tended by their parents in areas behind the colony nest sites). One Forster's Tern was sighted on April 10, however, significant numbers were not observed until April 17.

A few anomalies are not included in the above data. Two nests were still incubating eggs on July 10. Both nests were assessed as having addled or infertile eggs, as the calculated minimum time the nests were being incubated was 51 and 54 days. The nests were thus not added into the data as being indicative of the normal chronology. Additionally, two new eggs were found on July 10 in a nest that had previously hatched its last chick on June 27 (No. 92). These eggs were found predated when the colony was again visited on July 27.

Survey data of the colonies on the downstream portion of Island No. 18 and on Island No. 19 indicated these colonies were slightly later in chronology than the main study site, perhaps one to two weeks. Nests were found where eggs were still being incubated on July 10. On June 29 two, three egg clutches, about forty yards from the main colony site at the Island No. 18 downstream colony, were found. These nests appeared to be in the river flood area, however, lower river levels were prevalent at this time. These finds, plus the two egg clutch found at the main study site on July 10, are the only hard evidence of a second breeding contingent hypothesized by Thompson and Tabor (Th 81).

The breeding chronology of the Forster's Tern illustrates the critical periods during which disturbance can disrupt the nesting cycle of the Forster's Tern and reduce the fledging success of the colony.

Nest Counts

To gain a better understanding of breeding success on the Hanford Reach area of the Columbia River, all the Forster's Tern colonies must be considered and their combined success assessed (Wahlake Slope is

included as well). Table 11 compares the results of previous nest survey results with survey data obtained during this study. The data indicate a significant decrease in total active nests, with two sites not even having colonies established in 1985.

Table 11. Locations and Comparative Counts of Active Nests on the Hanford Reach and Wahluke Slope

Colony Site	Nest Count (Site Visits)			
	1977 ¹⁾	1978 ¹⁾	1983 ²⁾	1985
Island No. 18 Upstream	--- ³⁾	---	---	81 (37) ⁴⁾
Downstream	---	---	---	71 (6) ⁵⁾
Total	228	228(2)	---	---
Island No. 19	50	50	---	27 (6) ⁵⁾
Island No. 20	126	126(2)	---	0 (6) ⁶⁾
Wahluke Slope	---	---	50	0 (1)
Totals	404	404	NA	179

1) Data are from Thompson and Tabor (Th 81).

2) Data provided by R. E. Fitzner (pers. comm.). Data is based on sighting of birds in vicinity and verifying occupancy by sighting at least a dozen nests.

3) A "---" indicates no data taken or available.

4) The number of site visits are for those made when the colony nests were active. Of the 81 nests, two were incubated well past the average incubation period without a hatching occurring, and 21 others (containing at least one egg) were abandoned prior to the completion of the incubation period.

5) Nest counts for the downstream colony on Island No. 18 and for the colony on Island No. 19 are the maximum count determined from

Table 11. (Cont.)

several independent nest surveys.

- 6) Island No. 20 was visited during the breeding season of 1984. Though nest counts were not made, a Forster's Tern colony was observed.

Chick Mortality

One way to assess the effect of disturbance is to compare chick mortality rates between colonies that were subjected to different disturbance pressures. One of the main study colony's primary "predators" was the investigator. There were no gull colonies on this part of the island; however, gulls, predominately Ring-billed, constantly overflowed the colony on their way to and from a flocking point at the tip of the island. The location of the flock varied with the river level, at times being approximately fifty yards or less from the colony. Curiously, one Ring-billed Gull located its nest near the tern colony (less than 5.5 meters from the nearest tern nest). The adults at this nest were frequently the object of tern aggression when the colony or a nearby individual nest site was disturbed.

Human disturbance on the other two island colonies was, for the most part, only during the infrequent and brief nest surveys. Once the surveys commenced, however, some members of the downstream Island No. 18 colony would often react to the investigator when landing the boat in the morning and when leaving the island in the afternoon. The boat was put ashore just upstream of the water split in Island No. 18 mentioned

previously (the colony was roughly 100 yards away). The reaction from this colony didn't occur until after the first detailed nest survey was made. This colony also had a large Ring-billed Gull and California Gull colony abutting on its downstream island end. There were no gull colonies on Island No. 19.

Table 12 provides chick mortality and rates for the three Forster's Tern colonies. Mortality is considered up to the time the chicks leave the original nest site. After this, mortality was not surveyed.

Table 12. Chick Mortality Prior to Dispersal from the Original Nest Site

Colony Location	Predator/Disturbance Frequency	Active ¹⁾ Nests	Total Chicks Hatched ²⁾	Chick Mort. ³⁾	Mort. Rate %
Island No. 18					
Upstream	Investigator:Frequent Gulls:Frequent but limited to birds flocking in vicinity.	58	154	25	16.2
Down-stream	Investigator:Infrequent Gulls:Frequent, gull colonies located adjacent to colony	68	158	21	13.3
Island No. 19	Investigator:Infrequent Gulls:Infrequent	16	30	4	13.3

Table 12. (Cont.)

- 1) Active nests used here differ from those listed in Table 11. for the Island No. 18 upstream colony, only 58 nests actually hatched at least one chick. For the downstream colony and Island No. 19, the nest counts are from the survey date when the most accurate count of dead chicks could be made (June 21).
- 2) Mortality rate was calculated by dividing the total number of chicks hatched into the number of dead chicks. For the upstream colony, this could be done directly. For the other two colonies, in order to estimate the amount of chick hatchings it was assumed that each active nest originally contained a three egg clutch (Table 13 data makes this assumption reasonable). Eggs that were not present were then assumed to have hatched a chick. Since the incidence of four egg clutches was low (one per colony), this method probably represents an underestimate of the chick mortality rate for the two colonies.
- 3) To be considered a mortality the chick had to hatch from the egg first. Some chicks were found dead inside the egg in the early ring stage. They are not included in the data. For the upstream colony, chick mortality was determined by almost daily surveys of individual nest status in the colony. For the other two colonies, it is based on walk-through surveys where active nests and dead chicks were counted. Parent terns did not remove dead chicks from the nest site.

Clutch Size and Hatching Success

Tables 13 and 14 provide additional data for the main study site to put the chick mortality data in perspective with other breeding success (productivity) parameters.

Table 13. Average Clutch Size at the Main Study Site

Clutch Frequency	Nests with Completed Clutches ¹⁾	All Nests
1	0	6
2	12	13 ²⁾
3	61	61
4 ³⁾	1	1
Mean	2.9	2.7

- 1) Completion was based on the observation that one egg clutches tended to be in nests that looked only partially constructed and were most likely abandoned. Two egg clutches were in nests that for the most part appeared to have their construction complete.
- 2) Includes second abortive nesting attempt at nest No. 92.
- 3) Second group of two eggs was layed at least five days later than first group indicating the likelihood that a different female layed the second egg group (nest No. 59).

Table 14. Hatching Success at the Main Study Site

Hatching Success for Those Nests Incubated and Not Abandoned Prior to Expected Hatching Dates				Hatching Success for All Nests Containing at Least One Egg			
No. Nests	No. Eggs Hatched	Total Eggs	Percent	No. Nests	No. Eggs Hatched	Total Eggs	Percent
60 ¹⁾	154	173	89.0	81	154	220 ²⁾	70.0

Table 14. (Cont'd.)

- 1) Includes two nests that did not hatch chicks, but incubated for a minimum of 51 and 54 days, respectively.
- 2) Includes second clutch at nest No. 92 and one egg that was found outside the nests and couldn't be assigned to any particular nest.

Chick Mobility

In general, on nest surveys, I found that a one or two day post-hatch chick generally stayed in the vicinity of the nest during a disturbance. Three days and older chicks did not. Almost all chicks tended to crouch at my approach, in many cases under the cover of Absinthe, Grindelia, Buckwheat, Lupine, or Mulberry (Figure 10). In those cases when they crouched among cobble their coloration still provided some camouflage (Figure 11). Table 15 provides data on chick mobility.

Table 15. Chick Mobility

<u>Days Post-hatch</u>	<u>First Observed Excursion from Nest No. of Chicks</u>	<u>Leave Nest Site Permanently No. of Chicks</u>
1	22	--
2	35	6
3	6	6
4	1	13
5	--	7
6	--	3
7	--	2
Mean	1.8 Days	4.0 Days



Figure 10. Chick Crouching beneath Absinthe



Figure 11. Chick Crouching Among Cobble

After leaving the nest site and prior to fledging, chicks are led by their parents to areas behind the colony where the vegetation provides cover and a loosely defined territory can be established. In general, or at least until they were older, chicks were not seen in the open near the water. Part of the June 21 survey at the main study site included a sweep behind the colony to attempt to locate the older chicks nearing fledging. This was initially made along the shoreline so that any movement by disturbed chicks would hopefully be inland. Though this worked at first, it became apparent that the mobility of the chicks allowed them to get ahead of the investigators and in some cases move towards water. About five chicks were seen in shallow water on one side of the island tip while on the other side of the island, a large group of twelve to fifteen (some by themselves) headed out and were caught in the swift current of the river. Though it appeared that the adults were trying to drive the chicks back to shore, the chicks remained in the current. The chicks were seen floating past the gull colony, adult terns flying overhead, on the lower part of Island No. 18. Where the chicks finally landed was not determined. This displacement was permanent and in some cases may have represented partial broods. The effect on fledging success was probably detrimental.

Fledging

Though fledging success is a factor in the productivity success of a species (reaching the stage of flight gains the fledgling the ability to avoid ground predators), it was not determined in this study. Aspects of a Forster's Tern behavior make this difficult to determine.

At the main study site, fledging did not occur at the nest site nor in the colony proper (nesting area). Within a few days of hatching, the adults and chicks left the nest site and took up residence among the vegetation behind the colony (mostly Absinthe which provided camouflage for the chicks). The chicks were not observed to form creches.

Before chick hatching occurred, the high water mark reached to almost three meters to some of the nests at the back of the colony. River levels were lower when the chicks started hatching and moving out of the nest sites. This provided the necessary room behind the colony for the broods to establish loose territories where the chicks could be tended in safety. Limited recapture of banded chicks and observation of brood movements indicated that broods tended to move straight out behind the colony from the original nest site, with no crossing over to the other side of the colony. Survey attempts behind the colony, to assess brood status, had only limited success as the chicks were difficult to find. Judging fledging from the blind also became difficult as the blind was located opposite to the direction of movement of the broods. For these reasons, any type of fledging success rate was difficult to determine.

For comparative purposes with other studies, however, a rough calculation of productivity success is possible up to the time the chicks left their original nest sites. This was done for the main study site. Table 16 shows the results.

Table 16. Productivity Success at the Main Study Site

(1) Total No. of Eggs Layed	(2) Total No. Eggs Which Hatched	(3) Chick Mortality	(4) Success Rate (%) = $\frac{(2) - (3)}{(1)} \times 100$
220 ¹⁾	154	25	58.6

1) Total reproductive effort of the colony

DISCUSSION

RECOGNITION BEHAVIOREgg Recognition Versus Nest Site Gestalt

Forster's Tern adults showed no ability to recognize their own eggs. Because the results were all negative (response to the experimental condition did not differ from that of the normal condition) and were independent of the stage of incubation, substitution trials are adequate to show recognition did not occur. Choice trials are not expected to produce any different conclusions. The choosing of ones own clutch would be random if any clutch at all would be chosen.

Initially, I had hypothesized that egg recognition would occur. Supporting this hypothesis were: (1) Forster's Tern egg ground color and markings were highly distinctive and variable (subjectively, they appeared to provide a signature system with adequate information capacity); (2) nesting on cobblestone islands on the Columbia River would result in relatively densely packed colonies on suspected uniform substrate; and (3) a related species, the Royal Tern, was shown to be capable of egg recognition (Bu 72).

Observations made along with the experiments provide insight into why recognition of eggs has not been selected for in the Forster's Tern. The nests of the Royal Tern are described as shallow scoops in the sand only occasionally lined or surrounded by bits of material (Bu 72). Nest density was 7.5 nests per square meter (Bu 72). Such a nest type in a crowded colony provides poor visual cues. Its general location and relationship to adjacent adults cannot be discounted, however, in aiding

the recognition process (Bu 72). Forster's Tern nest sites were more distinctive in appearance than anticipated. (Figures 10 and 12 show typical nests). Additionally, they tended to be constructed near a prominent vegetational feature. This latter point is primarily subjective. Relative data was collected along with other nest data. The investigator took measurements on vegetation that appeared to represent a significant feature of the nest gestalt. Further quantitative work is needed to determine if vegetation serves as landmarks or simply as cover protection from the weather. Tables 17 and 18 provide data on the variability of nest measurements, substrate usage, and the vegetation by which nests were commonly located.

Comparison of the nest measurement data (cup and nest diameter) with that obtained for this species in a marsh habitat (Mc 71), show a trend for smaller, less variable size nests, for terns nesting on the Columbia River islands. In both studies, nest diameter was highly variable in comparison to other measurements. Cup depth in the Columbia River study (obtained after chick hatching) is comparable to the pre-hatching cup depth data of McNicholl (Mc 71) but not to the post-hatch data, where the reduction in depth was significant. The larger construction of the marsh nests may be due to their location on unstable substrate (i.e., floating vegetation). Interpretation of cup depth measurements and changes requires more data.



Figure 12. Typical Nest

Table 17. Nest Measurements¹⁾

	Cup Diameter (cm)	Cup Depth (cm)	Nest Diameter (cm)
Range	9 - 14	1 - 3.5	15 - 42
Mean	11.9 ± 1.1 ²⁾	2.4 ± 0.5 ²⁾	22.4 ± 4.6 ²⁾

1) Sample size equals 72 nests. Only those nests whose construction appeared complete and included a nest cup are included in the data.

2) One standard deviation

Table 18. Nest Substrate Usage and Proximate Vegetation

	Substrate						Proximate Vegetation				
	Cobble	Buck ¹⁾	Grin	Abs	Sand	Lup	Abs	Grin	Buck	Mul	Lup
No. Nests ²⁾	68	20	6	4	2	1	55	20	8	6	2

1) Abbreviations: Buck = Buckwheat; Grin = Grindelia; Abs = Absinthe; Lup = Lupine; Mul = Mulberry.

2) Substrate usage is based on a total sample size of 72 nests; 40 of these nests only had cobble as substrate, buckwheat constituted the only substrate for four nests (nests were built right on top of the plant), and all other nests had substrates of mixed types.

Proximate vegetation is based on a total sample size of 73 nests.

The location of its own nest with respect to its neighbors may also be an important recognition feature for the Forster's Tern. The average distance between nests (n=79) was found to be 3.5 ± 1.9 meters (one standard deviation), with a range of 0.9 to 12.7 meters. Nest density

ranged from 0.01 to 0.05 nests per square meter, depending on location in the colony. Nest location apparently was more dependent upon the proximity of vegetation types and sizes and not proximity to other tern nests; however, a minimum distance would still be expected based upon territorial considerations. The minimum distance measured involved an unoccupied nest. The minimum distance between two adjacent occupied nests was 1.8 meters. By comparison, McNicholl determined mean nest proximity distances of 0.8 meters and 6.8 meters, for nests on muskrat houses and floating vegetation, respectively (Mc 71).

Direct recognition of the eggs by Forster's Terns may be unnecessary for the incubating of the correct clutch. Both sexes take part in incubation with frequent exchanges. Most approaches to a nest were made with the nest already occupied (occupation frequency approximately 98 percent, Table 2). The visual presence of a mate and the invariant vocal exchange between the returning bird and the incubating bird would provide strong contextual cues for recognizing the correct nest. When approaching the nest, the returning tern would invariably use the fish call or trill call (mostly the fish call when the nest was occupied). The incubating bird frequently responded with the begging call. The possible recognition value of the fish call has been previously presented. When the incoming bird finally landed at the nest site, further fish and pair bond calls were given. Either bird could give one or the other call. If an incoming bird approached the wrong nest (this frequently occurred), the nest occupant often responded with a protest call and display; and if the intruder got too close, with a scream call. In extreme cases, the incubating bird came off the nest

to drive off the intruder.

Following colony upflights or when individual nests were infrequently left unoccupied, returns were usually made directly to the correct nest. Circling or hesitancy to land was attributed more to the bird's reaction to disturbance. With the nest unoccupied, the returning tern would have to rely on the nest site gestalt (nest contents having been ruled out for the egg stage) for its recognition cues.

Instances of mistaking the incorrect nest when the nest was already occupied may be indicative of the incoming tern not using the physical setting of the nest as its main cue for recognition when the nest was occupied. Otherwise, there shouldn't be a difference in the ability to find the nest whether it was occupied or not. Instead, recognition signals between mates were being used and when these failed the incorrect nest was chosen. The high noise levels of the colony may have contributed to this. With high nest occupancy during the incubation stage (the eggs would be visible a minimal amount of time), using one's mate for recognition of the correct nest would have high selection pressure.

Chick Recognition

For parent-chick or chick-parent recognition to occur in a species, there must be a selection pressure causing its development. Colonicity by itself is not sufficient (Be 81c). Circumstantial evidence (i.e., chicks location) may be all that is necessary to ensure care of the correct offspring. Intermingling of chicks, however, when parental care is still needed, would make some form of recognition essential (Be 81c).

Forster's Tern chicks were not observed to form creches after leaving the nest site. Their parents tended them in loosely defined territories behind the colony nest sites. Intermingling, if it occurs, may not be extensive. However, the movement of chicks to water as a group, observed on June 21, may indicate a potential for creching behavior. If the recognition process is facultative (i.e., dependent upon present environmental conditions and not on selection pressures acting throughout a species evolutionary past) for this species, it may be capable of recognition, yet not have shown it in this study. Beecher has described this concept of facultative recognition using gull species as an example (Be 81a).

Considering the above, the limited results from the chick alteration experiments allow only tenuous conclusions. The early mobility of the chicks (Table 15), especially as exemplified by the permanent movement of the two day post-hatch chicks away from the original nest site, would tend to make it necessary for some form of recognition, if it occurs, to develop within the first day or two following chick hatching. Brood movements, where chicks were moved out independent of each other, appear to rule out sibling recognition as necessary prerequisite to this movement.

The results of the chick alteration experiments would tend to indicate that visual signatures, at least at this stage, are not being used by parents to recognize chicks. Buckley and Buckley quantified the variation in Royal Tern chick down and soft part (i.e., bill, legs, and feet) colors showing their value as a signature system, but one that may be supplemental to a vocal system (Bu 70). Beecher later quantified the

information capacity of the Royal Tern chick down and soft part system (Be 82). For this species a visual recognition system is feasible. Buckley and Buckley also pointed out that because Royal Terns nest on islets free from mammalian predators, the coloration system is not needed as a protection from predation and that it could have evolved as a result of selection pressures for recognition in a creche forming species (Bu 70).

The value of the Forster's Tern chick's physical appearance as a signature system cannot be evaluated since the chicks were not quantified as to their color variation in this study. The chick appearance can, however, be evaluated qualitatively as an anti-predator device. Chicks were at times difficult to spot even when they crouched in the open (see Figure 11). Though the islands of the Hanford Reach are generally free of ground predators, the normal nesting habitat of the Forster's Tern is the marsh (Be 21 and Mc 71). McNicholl found mink to be an occasional predator on Forster's Terns in this environment (Mc 71). Since Forster's Terns also nest in association with aerial predators (e.g. gulls) the selection pressure for chick coloration (and perhaps egg) for cryptic purposes would be strong.

Since Miller and Emlen concluded that in Ring-billed Gulls recognition by parents of chicks was by visual means (Mi 75), it would be interesting to quantify the down and soft part coloration of Ring-billed Gull chicks to see if this signature system had the necessary information capacity.

Chick comportment cannot be discounted as contributing to the recognition process as discussed by previous investigators (Be 79 and Mi

75). Three observations from this study, however, on adult reaction to chicks present conflicting data. First, on the day nest No. 29 started moving its brood, the three day post-hatch chick did not leave the nest vicinity at the same time as its older sibling (five days post-hatch). At times it was unattended by either parent. At one point the chick wandered from the nest area and into the nesting area of nest No. 28. The adult on nest No. 28 came off the nest when the chick got within about 0.75 m of its nest and pecked at it twice. The chick immediately crouched; it had been erect and vocalizing to this point. The adult then ignored the chick. Second, the unaltered chick in the chick alteration experiment at nest No. 58 was pecked by the adult when it first approached the nest. Third, and also occurring on the day of a brood movement, involved a nest of three chicks (No. 7). An adult that had just returned to the nest site appeared agitated. The chicks were scattered about the nest site and began approaching the adult, who responded by pecking two of them. The chicks immediately crouched and were no longer pecked.

Role of the Fish Call in Recognition

If a visual system is ruled out, albeit by limited quantifiable results, then what recognition mechanism is at work? The most plausible system would appear to be a vocal system. Numerous investigators have identified vocal signature systems as the key to a recognition process. The question then becomes: In what direction is the process going? Are chicks recognizing their parents' voices and orienting their behavior

accordingly? Are parents recognizing their chicks' voices? Is the system mutual?

The fish call of the adult is a possible identification call. Though extensive quantifiable information could not be obtained from the fish call sonagrams, the form of the call appears to lend itself for use as a high information capacity system. In some respects, its form is similar to the fish call of the Sandwich Tern, whose possible use as a recognition signal has already been quantified (Hu 68).

The Figure 4 fish call sonagrams allow some subjective interpretation. The first and second pair of calls appear to have been by different individuals, with the same individual making each call of a pair. Individual identities were not confirmed for the calls that are similar (i.e., each mate could have made one of the calls). Further data would be needed to identify what features of the call are important for recognition. The sonagrams show frequency and temporal patterning but not amplitude changes. The first two are probably of most importance for the Forster's Tern.

Some species of birds have been found to have quite discriminative time resolution (Wi 75), implying that temporal patterning can be used effectively for identification. The high background noise associated with colonial nesting may favor the use of temporal patterning (Fa 82). For a bird that calls often in flight, as Forster's Terns often do when returning to the nest, a short duration call may allow for effective communication. For short calls, frequency structure also may be important for providing identification cues (Wo 78).

The few sonagrams made from Forster's Tern chick calls give little

indication of being useable as a signature system. A chick vocal signature system needs further investigation. Perhaps the chick begging call serves as the signature system since it is a response to the fish call. Alternately, selection pressure may be only on a chick-parent recognition system. The chick may not be under any selection pressure to develop individual identifiers, visual or auditory. The chick's recognition of its own parent may be sufficient to ensure its care.

The context in which the adult fish call is used is strongly indicative of its possible role as an identification signal. In nest exchanges it functions as a recognition signal between mates. A signature system functioning between adults could also be used in chick-parent recognition. Whether adults and chicks make use of the same signature system and whether their discriminative abilities differ is not known.

Use of the fish call when returning to the nest with food continued and increased in frequency with chicks present in the nest. The fish call vocalization continued after landing, as the parent searched for a recipient for its catch. It became the predominant call heard by the chicks in relation to their parents. Its association with feeding would tend to strengthen the call's use as parent-chick bond mechanism. The chick associates feeding with a particular call given by a particular adult (Ev 80).

Following disturbances and when broods were being moved, the adults used fish calls to attract their chicks whether or not they had food to offer. The chicks appeared to orient towards the vocalizations. If the nest was still occupied, the adult would give the fish call while

sitting in the nest, with the chick returning the call in an antiphonal exchange. Since following a disturbance, an older chick may not return for a period of time (see previous comments), it is not known what triggered the adult in initiating the fish call. For brood movements the adult would either circle overhead orienting the chick to a particular direction of travel or even proceed on foot ahead of the chick. In both cases the fish call was given while leading the chick. When first approaching the chick following a leading exercise, the pair bond call was also given. From the foregoing qualitative information, a strong argument can be made for the adult fish call functioning as the signature system by which Forster's Tern chicks recognize their own parents.

REACTION TO DISBURBANCE

The basic result of disturbance was that it kept a nesting pair off their nest. Had this occurred during the egg stage and during hot weather (with clear skies), the eggs could have overheated. Colder and wetter weather was a problem for the chicks, at least while surveys kept the adults off their nests. Colder, wetter weather occurred when the chicks were just beginning to hatch in significant numbers (early June - see Appendix Figure 1). The chick mortality rate was the highest during this time, probably due to the inability of chicks to thermoregulate.

The initial purpose for the surveys in the other two colonies was to determine if my presence at the main study site was causing a higher than natural chick mortality rate. I expected to find lower rates of mortality at the other colonies. The fact that they are comparable may

be due to a number of factors, but excludes investigator disturbance as the surveys were relatively brief and in milder weather.

The downstream colony on Island No. 18 experienced constant disturbance pressure from the adjacent gull colonies. Observations at the main study site (with less gull pressure) indicated adult terns spent a large amount of energy protecting their eggs and chicks from gull predation. The terns generally reacted to a gull flight through the colony with a mobbing response. This response was judged successful since egg predation was not observed until the colony was reduced in number (six nests left). The gulls could then be bolder as there were fewer terns to defend the nest sites. Direct chick predation was not observed. The increased gull presence at the downstream colony appeared to cause some chick mortality. This was due to nest inattentiveness of the adult terns. The gull presence also appeared to affect brood mobility out of the nest areas as older chicks (week or more post-hatch) were found within the nest areas during surveys.

Chick mortality at Island No. 19 may be inaccurate due to the small sample size. Additionally, the colony may have been comprised of terns that were forced from Island No. 20 due to the expanding gull colonies and re-nested in less suitable nest sites. The sparse vegetation provided less cover and the colony appeared to be later nesters. The colony could have also been younger birds, nesting for the first time, with the lower breeding success characteristic of young birds. No more than two live chicks were found at any one time on this island during surveys.

Forster's Terns are easily disturbed. I frequently observed the

colony, either all or part of it, engage in upflights. These occurred in reaction to a disturbance by either the investigator, gulls, alarm calls of other bird species, boat or air traffic, or in many cases to an unknown cause. During an upflight the adults would leave their nests in unison, circle the area briefly and return. Individuals and even the entire colony returned to the nests at different rates. The tendency to leave the nest and the rate of the return were affected by the level of the disturbance, the state of the nesting cycle, and the weather. In general, adults which had chicks ready to hatch tended to "sit tighter" and return earlier. Hot weather had a similar effect.

When I approached the colony each morning, the distance at which individuals flew out to protest my presence decreased as hatching approached. McNicholl (Mc 71) found similar results for this species. The investigator effectively represented the only ground moving predator that the terns had to deal with at the main study site. During the actual surveys, the agitation of the entire colony increased as hatching neared. When there were only eggs present in the colony, the terns tended to circle high overhead and give the protest call while I did the survey. With chicks in the colony, begging calls (initially observed associated with just gulls) were used and low swoops were made at my head. The aggression level didn't pick up significantly until the lone Ring-billed Gull nest's eggs began to hatch. The adults at this nest consistently harassed me while I was outside the blind even when some distance away. The tern pair at nest No. 7 started hatching chicks soon after this. This was the only time I experienced direct physical aggression from the terns. The adult(s) in

this area of the colony would hit me on the head with their feet and give the attack call as they passed through the bottom of the arc of their dive.

Reaction of chicks and adults with chicks is another indication of the impact of human disturbance. Forster's Tern chicks are highly mobile. They are capable of walking and leaving the nest temporarily when less than a day old. Permanent movement from the immediate nest area occurred a few days later. During this stage I noticed that at least three adults at nests closest to the blind showed agitation towards the presence of the blind on the day of movement. Additionally, it appeared that adults nesting closest to the blind tended to move their chicks at an earlier age. This impression was gained by observing the manner in which the broods were moved. The younger chick, usually two days post-hatch, tended to lag behind its sibling(s) and was more hesitant to leave the original nest site. A parent remained behind and tended it and in some cases wasn't successful in moving it an appreciable distance until the next day.

MANAGEMENT CONSIDERATIONS

Table 11, which shows comparative data on Forster's Tern active nests counts on the Hanford Reach, indicates a significant decrease in the total amount of active nests and in the sites colonized between 1985 and previous years. The absence of a colony on Island No. 20 has already been discussed as being due to the expansion of the California and Ring-billed Gull colonies there. Forster's Tern adults were seen in the vicinity of Island No. 20 in early May; however, no nests were ever

seen established. Nest counts of the gull species were not made, so that direct comparisons with the data of Thompson and Tabor (Th 81) cannot be made. Still, gull nesting appears to be increasing.

In general, vegetation around the gull nests was more open and was not indicative of an Absinthe dominated plant community. Intrusion into the previous Forster's Tern colony area on Island No. 20 was by late nesters and may have been into habitat less preferred by gulls. California Gulls typically are the first to establish nest sites among the Larids. Ring-billed Gull colonies tend to establish around the fringes of the California Gull colony closer to the water but still well above it. Forster's Terns are the last to establish nest sites and generally nest closest to water (R. E. Fitzner, pers. comm.). Flooded Forster's Tern nests on any island were not found and it is not known if any of the gull nests on Island No. 20 were flooded; however, being on the tip of Island No. 20, they were the closest gull nests to water.

Increasing gull populations may continue to cause a loss of suitable nesting habitat for the Forster's Tern. The late nesting Forster's Terns on Island No. 19 (possibly emigrants from Island No. 20) appeared to nest in less preferred habitat, even though they did not have to contend with an extensive gull presence. Table 11 indicated that a Forster's Tern colony has previously existed at the Wahluke Slope marshes as late as 1983. This area was surveyed on June 25 with the belief a colony would be present (possibly supplemented by individuals emigrating from Island No. 20). No Forster's Terns were found. The previous two winters were possibly detrimental to the marshes' fish population, reducing the immediate food supply (R. E. Fitzner, pers.

comm.). Though this is possible, Forster's Terns are capable of traveling to the Columbia River to feed. Another possibility is agricultural chemical contamination of the runoff water entering the marsh. The overall drop in nesting pairs, however, could be the cause of the lack of a colony at Wahluke Slope and be indicative of a decrease in the number of adults that are returning to the area. A number of cause and effect relationships are possible. The lack of suitable nesting areas may be causing a reduction in returning terns. Alternately, the lack of returning terns may be allowing "fringe" nesting gulls to utilize sites of a less suitable nature for gulls. Possibly, a certain number of terns may effectively establish and maintain a colony against expanding gull colonies comprising a later nesting contingent.

If site tenacity as described by McNicholl (Mc 75) is truly a characteristic of the Forster's Tern, then a reduction in breeding pairs could also be due to previous declines in the breeding success of the Hanford Reach colonies. To support this hypothesis, it would be necessary that the nest habitat conditions not have changed. Specifically, the nest habitat remains suitable for the rearing of broods and is not the reason for decreased occupancy. To be complete, a possible change in the survivorships of adults and young after leaving the islands would also have to be considered as a factor in the population decline, unrelated to conditions on the Hanford Reach.

I have no data that relate public access to the Hanford Reach islands and breeding success of Forster's Terns. Previous investigators have indicated the detrimental effects on Canada Geese of public access

when allowed during the breeding season (Ha 71). There is a potential for the human presence to seriously disrupt the breeding cycle of the Forster's Tern. The causes of nest abandonment have not been determined by this study. Roughly a quarter (21 of 81) of the nests at the main study site, containing at least one egg, were abandoned prior to the completion of incubation. Such data were not taken for the other two, less disturbed (by the investigator) colonies. Though direct desertion caused by human disturbance was not observed, it is possible the activities of the investigator at the main study site simulated the disturbance pressure of the gull colonies on the other Island No. 18 colony. The similarities of chick mortality rate between the two colonies probably indicate this similarity. The unlikely alternative would be that only natural mortality was at work in both colonies and the results at the main study site were independent of investigator presence.

The nesting chronology shown in Figure 9 indicates that hatching at the main study site was completed before the end of June. Within two days of the last hatching, all the chicks had moved to locations between the shoreline of the island and the original colony nest sites. From the blind, the chicks were difficult to spot. This movement from the relatively conspicuous nest sites to the cover of the shoreline Absinthe community, apparently provided the mobile chicks with a relatively safe area to continue their development until fledging. The inadvertent driving of chicks into the swift river current on June 21 illustrates, however, their extreme susceptibility to disturbance by a land predator.

With the first confirmed fledging occurring on June 28, the bulk of

the chicks would not reach fledging until after the islands were opened to public access (see Appendix Figure 1). This condition could be a major factor in the declining population of the Forster's Tern on the Hanford Reach. As an aid to improving the breeding success of the Forster's Tern on the Hanford Reach, strong consideration should be given to extending the restrictions on public access on, as a minimum, islands containing Forster's Tern colonies. These restrictions should be at least until July 15, or until the majority of the chicks have fledged.

Additionally, it is recommended that water samples be taken in the marshes of the Wahluke Slope and analyzed for environmental pollutants. The fish population should be surveyed to determine its potential as a food source. These two measures may aid in identifying possible causes for Forster's Tern abandonment of the marshes. Because of the loss of tern nesting sites on the islands (due to the expanding gull populations) it may be beneficial for the marshes to be restored to suitable nesting habitat for the Forster's Tern.

Finally, to better quantify the Forster's Tern population status, at least annual nest surveys covering other possible colony location sites in eastern Washington, should be performed. Accurate surveys may indicate Forster's Tern population and distribution changes beyond the capability of this study.

CONCLUSIONS

Forster's Terns, nesting on cobblestone islands of the Hanford Reach of the Columbia River, show no ability to recognize their own eggs, as shown by substitution trials and alterations of egg markings. The ground coloration and markings of the eggs are hypothesized to be for cryptic purposes. Parent-chick recognition capabilities are not conclusive. Observed problems with investigator disturbance of the main study colony and other factors such as early chick/brood mobility, precluded the gathering of anything but limited experimental data. Still, the results of two chick alteration experiments appear to rule out recognition by visual means. It appears an adult tern may use nest site gestalt features and recognition of its incubating mate to ensure it cares for the correct offspring in the egg stage and initially in the chick stage. For the chick stage, parent-chick recognition, if it occurs, should occur prior to the onset of permanent brood movement or within the first few days post-hatch.

Qualitative and limited quantitative data gathered on Forster's Tern calls indicate that the most likely mode of recognition in this species is by vocal means. The adult fish call appears to contain the elements needed to function as a signature system. Its use in situations such as bringing food to a mate and chicks, leading chicks, and nest exchanges, point to its use in acting as an individual identifier. The reaction of chicks to this call would suggest that chick-parent recognition occurs by this mode.

The limited quantitative data gathered on chick calls did not show

characteristics anticipated to be part of a signature system. The calls recorded were probably disturbance calls and not selected to function as identifiers. General chick comportment and specific reaction to an adult's signature may be the means of parent-chick recognition for this species. Choice trials involving playback experiments are suggested as a means for testing parent-chick and chick-parent recognition.

Nest counts of Forster's Terns in the Hanford Reach indicate a significant decline in the population of this species in recent years. The decline is hypothesized to be due to a possible combination of factors. California Gull and Ring-billed Gull population expansion appear to have displaced Forster's Terns from preferred nesting habitat. Also, human access to colony sites during critical periods of chick development could, through disturbance, be causing a reduction in the breeding success of the species. The bird's reaction to the human presence and specific behavioral reactions [i.e., older chicks (pre-fledges) head to water upon disturbance] make it highly susceptible to disturbance pressure.

It is recommended that access control on islands containing Forster's Tern colonies be extended a minimum of two weeks. Additionally, the Wahluke Slope marshes should be evaluated as to their suitability for Forster's Tern nest habitat. Such an evaluation should determine the underlying causes for previous Forster's Tern abandonment of the marsh and identify the necessary corrective measures for restoration. Finally, nest surveys of at least a yearly nature should be performed to better quantify Forster's Tern colony size and distribution throughout eastern Washington.

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APPENDIX

Defining a chick's age:

In order for data relating to a Forster's Tern chick's age to be used for comparative purposes, a chick's age in this study was defined as follows:

1. Chicks found with down still wet, but no shell present in the nest, were considered to be one day post-hatch chicks.
2. Chicks found in the process of hatching or still wet, with the shell still in the nest, were considered zero days old.

Appendix Table 1. Egg Dimensions¹⁾

Nest No./Egg No.	Length (mm)	Max. Diameter (mm)
71/1	44.85	30.85
2	44.85	29.80
3	43.10	30.70
64/1	43.00	30.80
2	43.80	30.65
60/1	41.85	31.75
57/1	43.25	29.40
54/1	40.85	30.75
2	44.20	31.00
44/1	42.55	30.40
27/1	45.35	30.95
2	43.55	30.10
1/1	45.45	30.75
Range	41.85 - 45.45	29.40 - 31.75
Mean	43.59 ± 1.37 ²⁾	30.61 ± 0.59 ²⁾

1) McNicholl (Mc 71) reported mean values of 42.9 mm in length (range 33.5 to 47.0 mm) and 30.9 mm in width (range 29.0 to 32.5 mm) for a sample size of 158 eggs.

2) One standard deviation.

Appendix Table 2. Hatching Interval Within a Nest (Three Egg Clutches)

Sample Size		16
Days:	2	12
	3	4
Mean		2.3 ¹⁾

1) Laying interval for a three egg clutch, based on limited data, appeared to be approximately an average of four days.

Appendix Table 3. Day from an Egg Stage Until Chick Emergence

Stage	Early Pip	Pip	Early Ring	Ring
Sample Size	59	17	9	3
Days: <1 ¹⁾	1	--	2	--
1	9	16	6	3
2	26	1	1	--
3	15	--	--	--
4	8	--	--	--
Mean	2.3	1.1	0.9	1.0

1) From the first observation of the stage until chick emergence took less than a day. For the egg in early pip (first found at 0630) a chick emerged less than 5.5 hours later (found at 1150).

Appendix Table 4. Days Between Egg Stages

Stages	Early Pip					
	Early Pip to Pip	to Early Ring	Early Pip To Ring	Pip to Early Ring	Pip to Ring	Early Ring to Ring
Sample Size:	13	10	2	1	2	1
Days: <1	--	--	--	--	1	1
1	8	3	--	1	1	--
2	1	4	2	--	--	--
3	3	3	--	--	--	--
4	1	--	--	--	--	--
Mean	1.8	2	2	1	<1	<1

Appendix Table 5. Average Incubation Time

Sample Size	Average (Days)	Range
6	23.8	23 - 26

Appendix Table 6. Parental Activity Frequency During the Chick Stage

Oldest Chick Age			
(Days Post-Hatch)	1	2	3
No. Nests	15	7	3
No. Tallies ¹⁾	275	110	50
Brooding - % ²⁾	94.9	94.1	95.0
Standing - % ²⁾	2.0	3.2	4.0
Feeding - % ²⁾	0.9	0.0	1.0
Not in Nest Vicinity - % ²⁾	2.2	2.7	0.0

1) Surveys of parental activity frequencies were by scan technique (Miles 1975), normally twenty times a day.

2) Normally each scan observation of a nest represented one data point. If both parents were present at the nest site, however, the data point was halved to account for the activity of both parents. Though this approach may introduce a small bias into the data, it was necessary to account for a condition such as: one parent was feeding a chick while the other was still brooding.

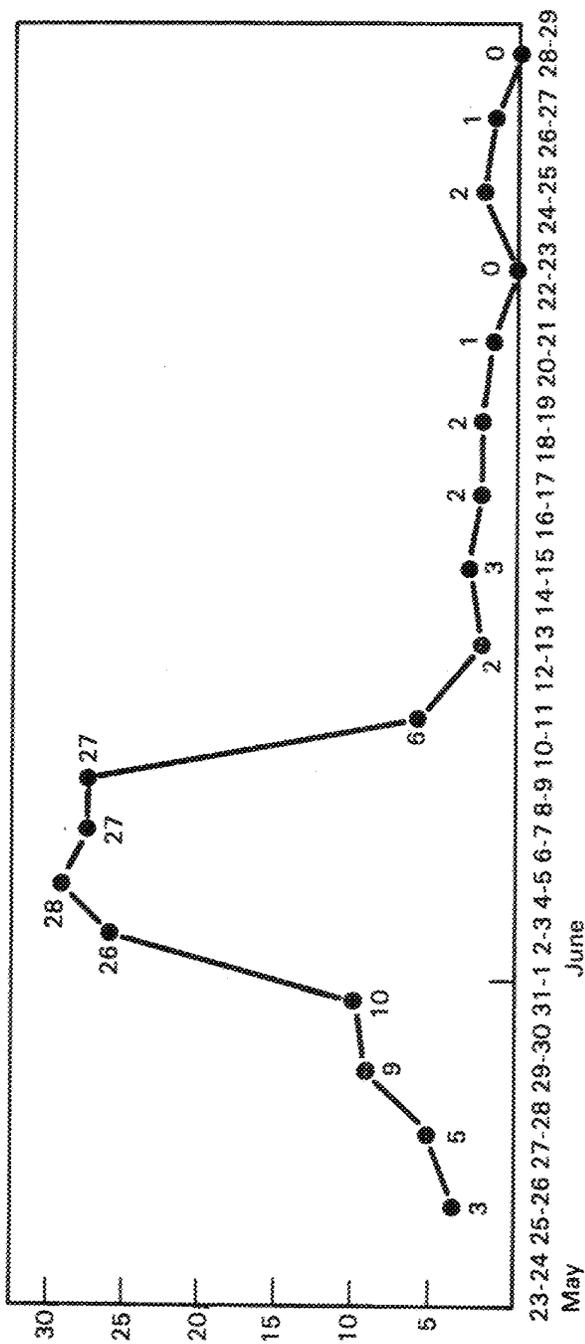
The percentages are in percent of total scan tallies.

Appendix Table 7. Chick Feeding Frequencies

Nest No.	Nest Status	Time period Observed	Number of Feedings		
			Total Attempts/ Freq./Hour	Total Successful/ Freq./Hour	Uncon- firmed Attempts
39	3 chicks: unknown ages, however, oldest not more than 3 days post-hatch.	1030-1400	6/1.7	2/0.6	1
26	2 chicks: both 2 days post-hatch.	0805-1035	5/2	2/0.8	--
26 ¹⁾	3 chicks: 2, 3 days post-hatch; 1, 1 day post-hatch.	0855-1225	12/4.8	9/2.6	--
59	1 chick, 1 day post-hatch.	0800-1030	2/0.8	1/0.4	2
59	2 chicks: 1, 3 day post-hatch; 1, hatching in progress at 0735.	0800-1000	3/1.5	1/0.5	--

- 1) Feedings occurred at 0945, 0953, 1004, 1034, 1134, 1139, 1143, 1148, and 1217 with additional attempts at 0917 (fish too big for chick), 1019, and 1159. Another feeding occurred after the observation period ended at 1237.

Appendix Figure 1. Distribution of Chick Hatchings at the Main Study Site 1)



1) Distributions were assigned in two day increments. This accounts for some of the inaccuracies in assigning chick hatching dates due to missing survey dates. For the June 6-7 and June 8-9 increments, larger uncertainties are present due to missing both the June 6 and June 7 survey dates and only performing a partial survey on June 8. Data from these dates was summed and arbitrarily split between the two increments.

