AN ABSTRACT OF THE THESIS OF

Loree Hennigar Havel for the degree of Master of Science in the Department of Fisheries and Wildlife presented on August 22, 1984

Title: Formation of Feeding Flocks During Winter by Dusky and Taverner's Canada Geese in Oregon

Abstract approved: Redacted for privacy

Robert L. Jarvis

Behavior and environmental variables influencing the formation of flocks of dusky [*Branta canadensis occidentalis* (Baird)] and of Taverner's Canada geese (*B. c. taverneri* Delacour) were studied on Sauvie Island, Oregon, during winter (Oct-Apr) 1981-82. Geese occurred most frequently (80%) in skeins segregated according to subspecies affinity (at least 91% dusky or at least 90% Taverner's). In contrast, subspecies composition of feeding flocks (flocks of feeding geese) was frequently (73%) mixed (11-90% dusky/10-89% Taverner's). During waterfowl hunting season, skeins composed of at least 90% Taverner's contained more geese, started approach and landing behaviors at higher elevations, circled more times before landing, and took a longer time to land than skeins composed of at least 91% dusky ($P < 0.001$, all variables). On the average, skeins of Taverner's approached larger fields, containing more geese, and located farther from a roost lake than skeins of duskys ($P < 0.001$, all variables). Out of landing skeins composed of mixed subspecies, a dusky Canada goose was the first bird to land more frequently than expected ($P < 0.001$) and a Taverner's Canada goose was the last bird to land more frequently than expected ($P < 0.001$). Taverner's frequented fields on privately owned land, while duskys were more often associated with fields on a state wildlife management area. I could determine no patterns for the relationships between subspecies composition of feeding flocks and/or skeins and distance of a field to danger, field crop, amount of water visible in a field, weather variables, time of day, or response to disturbance. Taverner's Canada geese exhibited significant "seasonal" changes in patterns of behavior and use of fields from waterfowl hunting season to post-hunting season. No significant changes were noted for dusky Canada geese between "seasons." It is hypothesized that the observed differences between dusky and Taverner's Canada geese (within and between "seasons") contribute to differential hunting vulnerability of these subspecies and to the inhibition of pair formation between individuals of different subspecies where these subspecies winter sympatrically.

FORMATION OF FEEDING FLOCKS DURING WINTER BY DUSKY AND TAVERNER'S CANADA GEESE IN OREGON

by

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INTRODUCTION

Dusky [*Branta canadensis occidentalis* (Baird)] and Taverner's Canada geese (*B. c. taverneri* Delacour) are two of six subspecies of Canada geese known to winter in western Oregon (Bellrose 1976:141-164). During the decade 1970-80, the relative proportion of dusky and Taverner's Canada geese wintering along the lower Columbia River and in the Willamette Valley, Oregon, altered dramatically. Dusky Canada geese comprised an estimated 95% of this aggregation of wintering geese in 1969-70 (R.L. Jarvis 1976, unpubl. report to Dusky Canada Goose Subcommittee of the Pacific Flyway Technical Committee). During winter 1975-76, nearly 45% of the wintering geese were Taverner's, and by 1979-80, subspecies composition was approximately 32% dusky and 67% Taverner's (R.L. Jarvis 1980, unpubl. report to Dusky Canada Goose Subcommittee of the Pacific Flyway Technical Committee).

During the recent influx of Taverner's into the traditional winter range of duskys, Simpson and Jarvis (1979) determined that these subspecies differed with respect to their winter distribution in western Oregon, their vulnerability to hunting, and certain aspects of their winter ecology.

Calculations of relative vulnerability to hunting indicated that duskys were more likely to be shot than Taverner's. In 1976-77, and 1977-78, duskys were 2.8 and 2.6 times as likely to be shot as Taverner's (Simpson and Jarvis 1979:232). Taverner's occurred in larger flocks than duskys (Simpson and Jarvis 1979:234) and qualitative observations showed that Taverner's located more often in the middle of, or on a rise in, a field. In 1977-78, the mean field size frequented by flocks composed primarily of duskys was smaller than for fields used by Taverner's (Simpson and Jarvis 1979:234).

Since approximately 1971, hunting regulations, hunting techniques, and refuge management regarding Canada geese wintering in western Oregon have been based primarily on information derived from research on dusky Canada geese (Timm et al. 1979). The changing subspecies composition of Canada geese wintering in western Oregon and the noteable differences in winter ecology and hunting vulnerability between dusky and Taverner's geese suggest that current dusky-based management regulations may be inadequate and/or inappropriate for the non-dusky segments of the wintering aggregation (Raveling 1969a, 1978a, Simpson and Jarvis 1979, Timm et al. 1979). Learning more about the variables that influence various aspects of the winter ecology of dusky and Taverner's geese is important to understanding their evolutionary ecology and habitat requirements, and to managing these subspecies as separate segments of a wintering aggregation.

The selection of food and feeding area during winter and spring are important components of goose ecology (Ankney and MacInnes 1978, Raveling 1979, McLandress and Raveling 1981, Ankney 1984). Feeding area selection by geese is known to be influenced by many variables, including subflock, population, or subspecies affinity (Marquardt 1962, Raveling 1969a, Grieb 1970, Newton and Campbell 1973, Koerner et al. 1974, Simpson and Jarvis 1979, and Zicus 1981). Learned behavioral responses as well as inherent behaviors specific to subspecies may affect feeding area selection or rejection by individual geese. The primary purpose of my study was to determine some of the behavioral and environmental variables that influence how, when, and where dusky and Taverner's Canada geese feed during winter. In particular, I wanted to test the hypotheses that there were no differences between dusky and Taverner's geese with regard to behavior and/or habitat use.

METHODS

Study Area

Fieldwork was conducted during one field season, 15 October 1981 through 18 April 1982 on Sauvie Island, Oregon, 40 km northwest of Portland (T.3N.,R.1W., Figure 1). The area consists of about 5,500 ha of privately owned, primarily agricultural land (crop and pasture) and 4,900 ha managed as a wildlife area by Oregon Department of Fish and Wildlife.

A substantial portion of Sauvie Island is seasonally farmed and flooded in order to attract waterfowl, and the area is a major stopover and wintering ground for Pacific Flyway migrants. Monthly waterfowl surveys on Sauvie Island during the study ranged from a minimum of 7,788 waterfowl (10 Feb 1982) to a maximum of 154,322 (18 Nov 1981). Canada goose counts during this period ranged from 2,542 (10 Feb 1982) to 28,906 (18 Nov 1981) geese (U.S. Fish and Wildlife Service unpubl. census, Wm. L. Finley National Wildlife Refuge, Oregon). Proportions of dusky and Taverner's Canada geese utilizing Sauvie Island varied over the study season (Table 1). The study population was composed of samples from this large and variable wintering group.

Hunting of waterfowl occurred on state and privately owned lands on Sauvie Island during the study. Public hunting on state owned land was scheduled for alternate days from mid October 1981 through mid January 1982, while hunt schedules for privately owned land varied from daily (rare) to weekend only hunts during this same time period. Overall, hunting pressure was "heavy" for the entire area throughout waterfowl hunting season. An unhunted, 1,300 ha lake (Sturgeon Lake,

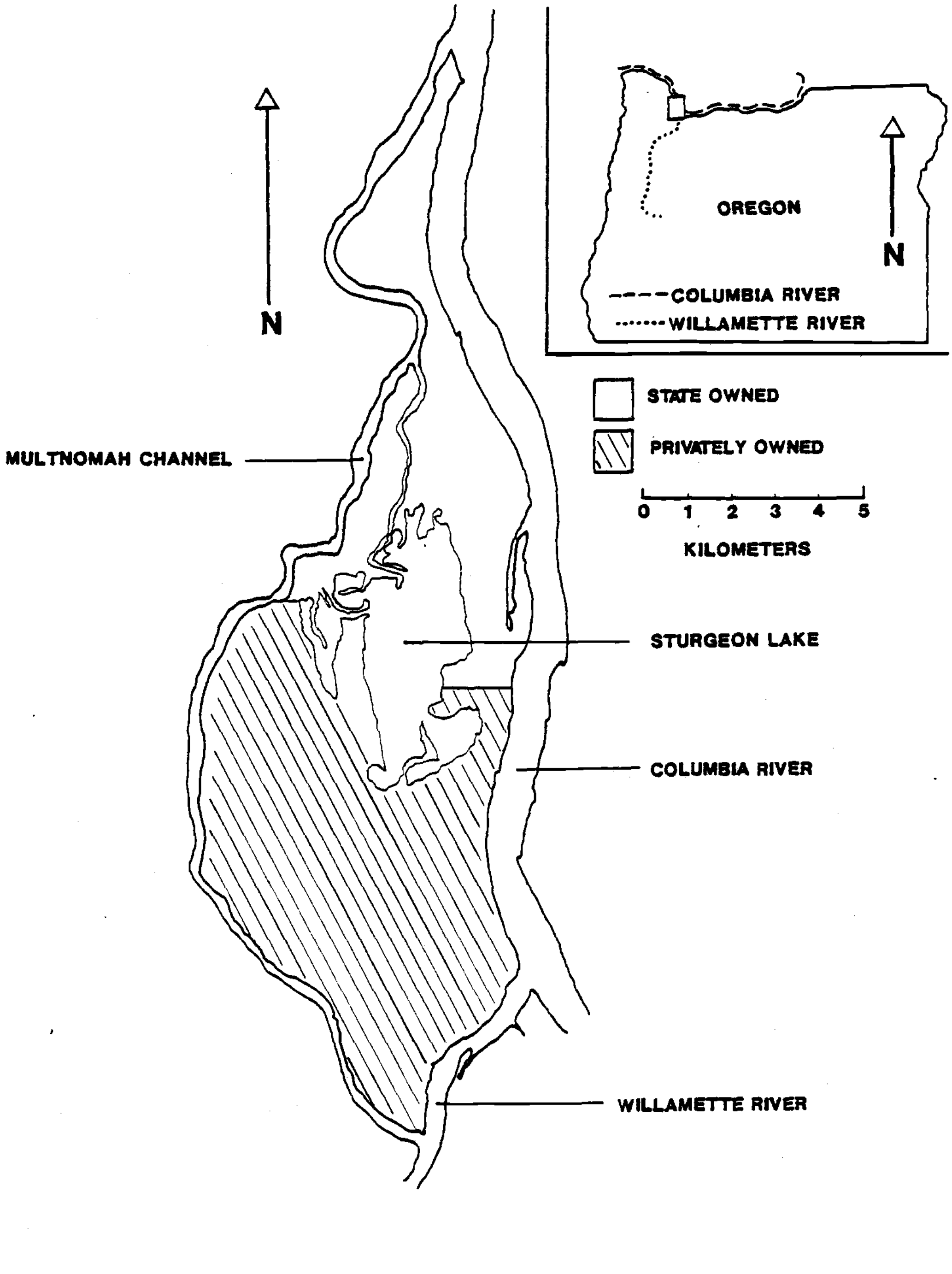


Figure 1. Location of study area in Oregon (inset) and map of Sauvie Island showing location of Sturgeon Lake and the distribution of land ownership.

Table 1. Estimated numbers and subspecies composition of Canada geese on Sauvie Island, Oregon, during winter 1981-82. From aerial surveys and counts from aerial photographs.

Census[1]		Estimated Subspecies Composition[2]		
Date	Number of Canada Geese Observed	Date	Percent Dusky	Percent Taverner's
18 Nov 1981	28,906	13 Nov 1981	31.1	68.9
30 Dec 1981	16,656	20 Jan 1982	49.3	50.1
1 Apr 1982	14,792	30 Mar 1982	8.9	90.6

[1] Unpublished census, U.S. Fish and Wildlife Service, Wm. L. Finley National Wildlife Refuge, Oregon.

[2] Estimated subspecies composition, R.L. Jarvis, Department of Fisheries and Wildlife, Oregon State Univ., Corvallis, Oregon.

Figure 1) probably served as an important sanctuary and roost for migrant and wintering waterfowl.

Data Collection

I observed goose flocks composed of single and mixed subspecies from a vehicle or blind located in or near fields where geese regularily fed (hereafter termed feeding fields). My observation periods generally spanned the time between sunrise and 2 hours post-sunrise. Periodically, observations were conducted throughout daylight hours and regular, qualitative observations were made at night.

I collected data on behaviors of geese as aggregations (hereafter termed feeding flocks) formed in fields. Characteristics of the feeding fields that flocks of flying geese (hereafter termed skeins) approached and/or where geese already fed were measured or noted. I recorded the responses of feeding geese to disturbance (e.g. vehicles, large birds overhead, loud noises, etc.) as disturbances occurred during observation periods. Weather conditions and time of day were recorded for all observations.

Formation of Feeding Flocks

I recorded data on numbers of geese, subspecies identity, and field approach and landing behaviors with the aid of binoculars, 20X spotting scope, tape recorder, tally counter, and split-time stopwatch. Variables associated with the formation of feeding flocks were designated as follows:

1. Number and subspecies composition of geese in skein approaching a feeding field (approaching skein).
2. Elevation of approaching skein (approach elevation).
3. Number of circular passes skein executed over a field before a) the first goose landed, b) the last goose landed, or c) the approach terminated (skein resumed flapping flight).
4. Time interval from the start of approach to time when a) the first goose landed, b) the last goose landed, or c) the approach terminated.
5. Subspecies identity of a) the first goose to land, and b) the last goose to land.
6. Number and subspecies composition of landing geese.

Number of individuals in, and subspecies composition of skeins were determined by observation and count. Identification of subspecies was on the basis of relative size and plumage differences as described by Delacour (1951, 1954:167-172) and Johnson et al. (1979:57). Data were not recorded when light level, heavy rain, fog, or distance from the birds prohibited accurate classification of subspecies.

I identified a group of flying geese as a skein when the individual birds were near (a few meters) each other and behaviorally coordinated with respect to turning, velocity, and/or direction of flight. Heppner (1974:160) terms this type of formation a "flight flock," while O'Malley and Evans (1982:1025) use a similar definition for a bird "flock." According to my use of the term, a single bird approaching a field also represented a skein.

I made an estimate of approach elevation and started to time and count circles for a skein when at least one skein member terminated flapping flight, "set" its wings in a glide, and began to lose altitude. I estimated the elevation of an approaching skein, and checked my estimates with Abney level measurements, the estimates of other experienced observers, and with known elevations of helium balloons.

When approaching skeins split up into two or more smaller groups, I timed these groups as independent units. When a skein initiated an approach but did not land, or only a portion of the approaching skein landed, I recorded the time interval and number of circles executed over the field until at least 50% of the skein resumed flapping flight. For portions of the skein that did land, I recorded items 1-6 as listed above.

On several occassions, a few cackling (*B.c. minima* Ridgway), lesser [*B.c. parvipes* (Cassin)], and/or Great Basin Canada geese (*B.c. moffitti* Aldrich) joined feeding flocks of duskys and Taverner's. I assumed that the influence of these other subspecies on the formation of flocks of duskys and Taverner's was insignificant, and did not include these other subspecies in any of my observations or counts.

Characteristics of Feeding Fields

The number and subspecies composition of geese feeding in a field were recorded as census scan samples (Altmann 1974:259) at 15-min intervals during an observation period. I defined fields as areas under one type of cultivation or use separated from adjacent fields by a ditch, road, fencerow, treeline, or by a change in land use.

I measured feeding field size, distance to Sturgeon Lake, and distance to the nearest danger. These measurements were accomplished with the aid of maps, black and white aerial photographs, and planimeter, supplemented with ground checks on selected fields.

I defined danger as a feature in or near a feeding field that could provide cover for a predator. Examples of danger found in or near fields included duck blinds, fencerows, ditches, farm equipment, and roads. Crop or use of a field, amount of water visible in a field, and field ownership (state or private) were determined by observation and interview.

Weather

I measured (temperature) or categorized (wind velocity, skycover, and precipitation) local weather conditions at the start of an observation period, and if I detected a change in a weather variable during a period. Daily barometric pressure trends (rise and fall) were obtained from the National Weather Service meteorological station at Portland International Airport, located approximately 48 km southeast of the study area.

Time of Day

I recorded clock time whenever I conducted a field scan for the number and subspecies composition of geese in a field and whenever a skein initiated a feeding field approach.

Disturbance

For each disturbance event, I determined the following by observation (items 1-5), calculation (items 6 and 7), or measurement (item 8):

1. Number and subspecies composition of geese in feeding field at the time of a disturbance.
2. Time of day when disturbance occurred.
3. Disturbance type (e.g. vehicles, large birds overhead, loud noises, etc.).
4. Initial response of geese to disturbance [e.g. none, vocalization, vigilance (Lazarus 1978:135-136), or flight].
5. Number and subspecies composition of geese remaining in field following disturbance.
6. Proportion of geese (percent of initial values) that flew from field at time of disturbance.
7. Change in subspecies composition of geese in field from pre- to post-disturbance.
8. Characteristics of feeding fields where observations of disturbances took place (e.g. ownership, field size, distance to Sturgeon Lake, and distance to danger).

Data Treatment and Analysis

The raw data were examined for normality, confounding relationships, and linear trends using scatterplots and Pearson product-moment correlation (Nie et al. 1975:276-287). Due to the high correlation between the number of geese in a skein and the number of geese landing from that skein (r = 0.995, N = 1376, P = 0.001) and between the subspecies composition of geese in a skein and subspecies landing (r = 0.984, N = 1254, P = 0.001), I used only the number and subspecies composition of geese in a skein in further analyses.

The two variables measuring the number of circles until geese landed (first and last to land) were so rarely different for a given case that they were averaged to derive the mean number of circles before a skein landed.

Examination of data collected before and after the Oregon waterfowl hunting season for 1981-82 revealed differences between the means for most variables (Table 2). Subsequent analyses were conducted on data partitioned by "season," where HUNT = data collected 15 October 1981 through 17 January 1982 (N = 893 for the number of skeins observed) and NOHUNT = data collected 18 January through 18 April 1982 (N = 483 for the number of skeins observed).

Within each season, I sorted the data into categories according to the subspecies composition of geese in feeding flocks and the subspecies composition in skeins. I designated groups (feeding flocks and/or skeins) composed of 0-10% dusky Canada geese (e.g. 90-100% Taverner's) groups of Taverner's, and groups composed of 91-100% dusky (0-9% Taverner's) groups of duskys. Flock and skein subspecies compositions between these endpoints were sorted by 10% intervals, and grouped as mixed Taverner's (11-50% dusky/50-89% Taverner's), mixed dusky (51-90% dusky/10-49% Taverner's), or mixed subspecies (11-90% dusky/10-89% Taverner's).

Table 2. Means and standard deviations for variables associated with Canada goose behavior and field use during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

Variable	Season	N	$\bar{x}$	SD
Number of Geese in Field	HUNT	836	869	1184
	NOHUNT	424	659	637
Approach Elevation (m)	HUNT	893	90	80
	NOHUNT	483	58	49
Number of Geese in Skein	HUNT	893	23	77
	NOHUNT	483	25	144
Number of Circles	HUNT	857	1.2	1.4
	NOHUNT	337	1.4	1.3
Time Interval to First Landing (sec)	HUNT	857	64.0	56.7
	NOHUNT	337	48.3	34.1
Time Interval to Last Landing (sec)	HUNT	856	71.3	63.2
	NOHUNT	337	60.8	49.4
Number of Geese Landing	HUNT	893	21	77
	NOHUNT	483	24	144
Field Size (ha)	HUNT	893	33.3	21.6
	NOHUNT	483	20.5	17.2
Lake Distance (m)	HUNT	893	1291	944
	NOHUNT	427	1388	729
Danger Distance (m)	HUNT	893	229	112
	NOHUNT	483	165	76

I determined the nature of associations between subspecies compositions of feeding flocks and skeins and other study variables, and associations among disturbance event variables through analyses of single and multi-factor contingency tables (non-parametric analogs to single and multi-factor analysis of variance). Chi-squared (χ^2) tests of independence or Kendall's Tau C statistics (Nie et al. 1975:223-228) were used as measures of the strength and statistical significance of associations. Tau C represents a comparison of the direction and magnitude of the differences between observed and expected frequencies over all cells of a contingency table for ordinal level (rank ordered with no assumptions of distance) or higher variables. Values for this statistic range from -1 to 1, where a value of zero indicates a lack of association between variables. A negative value of Tau C is indicative of a negative association between variables. I determined significance of associations by comparing the relative size of the statistic for a given number of degrees of freedom with tabled values.

I used single and two population (pooled variance estimates) *t*-tests (Nie et al. 1975:267-274) to test for differences in subspecies response to disturbance within and between seasons.

I made comparisons of the means for selected variables associated with behavior and use of field by skeins and feeding flocks of duskys and Taverner's using un-paired *t*-tests (pooled variance estimates).

Principal components analysis (P.C.A.) with Kaiser normalization and varimax rotation (Nie et al. 1975:468-508) was employed to discover the variables or variable combination that accounted for the greatest amount of variation in the data grouped by subspecies composition and season. Variables were selected for use in P.C.A. according to each variable's factor loadings ("high") and communality estimates ("low"). I used discriminant function analysis and classification (Nie et al. 1975:435-462) with the actual subspecies identity as the grouping variable to check the interpretation of other analyses and to elucidate subsets of variables that best separated subspecies with regard to formation of feeding flocks and use of feeding fields.

RESULTS

Distribution of Observations by Season

The frequency of observations of groups of geese (feeding flocks and skeins combined) composed primarily either of dusky (91-100% dusky) or of Taverner's (0-10% dusky) Canada geese was different (χ^2 = 174.1) for the hunting and post-hunting seasons. During HUNT (*N* = 1712), about 29% of my observations were of groups of duskys, and 26% were of groups of Taverner's. During NOHUNT (*N* = 906), groups of duskys were observed much less frequently (10%) than groups of Taverner's (47%). Total numbers of duskys in the study area declined from January through April, while total numbers of Taverner's increased (Table 1), which probably accounts for the decreased observations of groups of duskys from HUNT to NOHUNT.

Subspecies Composition of Feeding Flocks and Skeins

While commuting from the roost lake to feeding fields, or from one field to another, geese occurred most frequently in skeins segregated according to subspecies affinity. I classified approximately 80% of the skeins observed during both HUNT (*N* = 893) and NOHUNT (*N* = 483) as predominantly one subspecies or the other (e.g. 0-10% dusky and 91-100% dusky). Skeins composed of mixed subspecies (11-90% dusky) represented < 20% of the total during either season (Figure 2).

In contrast to skeins, subspecies composition of feeding flocks was frequently mixed. I observed feeding flocks of mixed subspecies

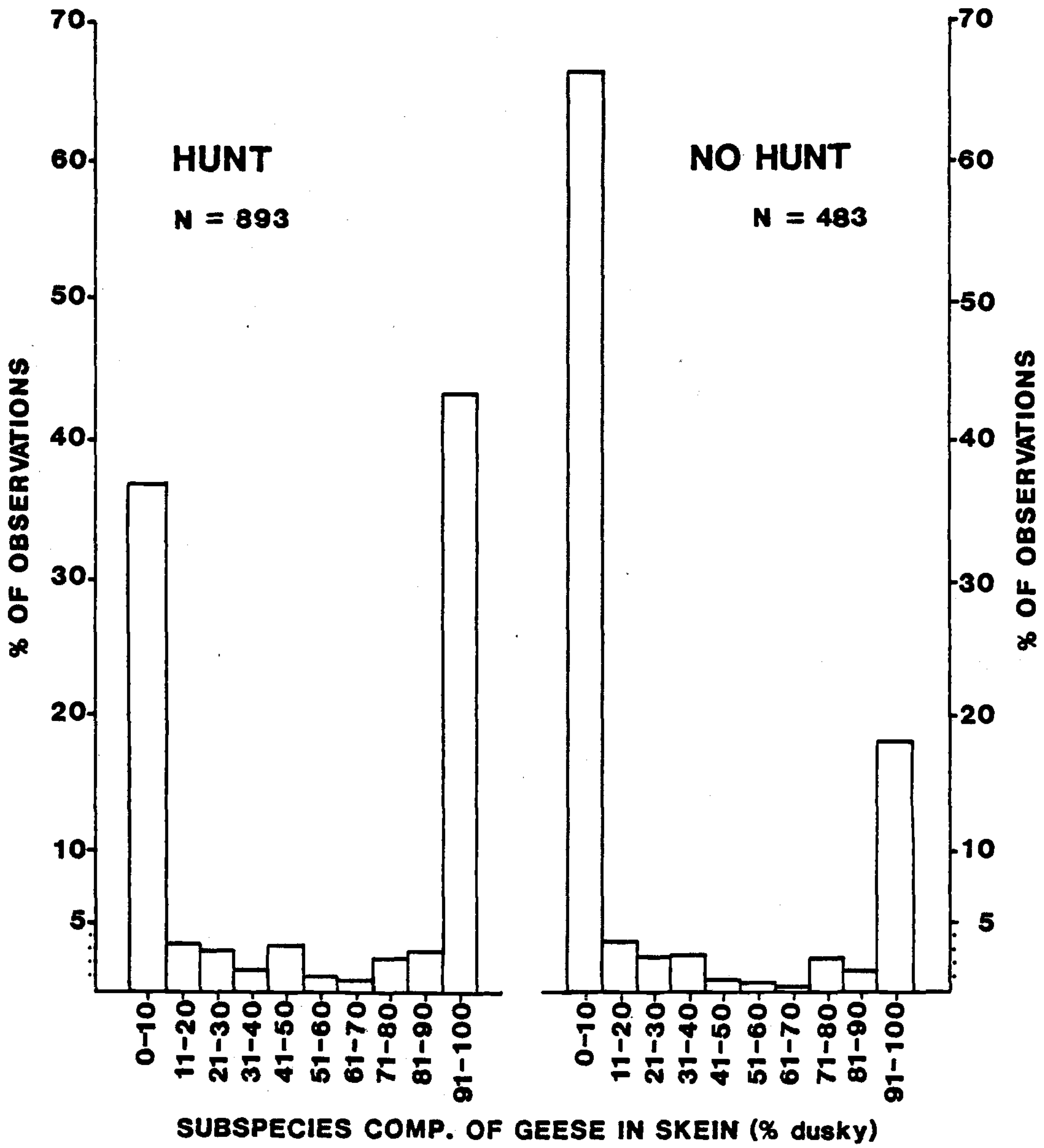


Figure 2. Frequency of observations of skeins of Canada geese according to subspecies composition (proportion dusky and Taverner's) during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

72% during HUNT ($\underline{N}$ = 819), and 74% of the time during NOHUNT ($\underline{N}$ = 423, Figure 3).

Formation of Feeding Flocks and Characteristics of Feeding Fields

Feeding Flocks: Dusky vs. Taverner's

During HUNT, the mean values for the number of geese in a field, the feeding field size, and the distance to Sturgeon Lake from a feeding field were significantly larger ($\underline{P}$ < 0.001, all variables) for feeding flocks of Taverner's than for flocks of duskys (Table 3).

Feeding flocks of Taverner's were observed in larger groups ($\underline{P}$ < 0.001) and in larger fields ($\underline{P}$ < 0.001) during the hunting season than flocks of Taverner's observed following the hunting season (Table 4).

Comparisons of feeding flocks of duskys and Taverner's within NOHUNT and feeding flocks of duskys between HUNT and NOHUNT were not evaluated due to the small sample size for duskys during NOHUNT ($\underline{N}$ = 4).

Feeding Flocks: All Categories of Subspecies Composition

In general, feeding flocks of mixed subspecies exhibited characteristics similar to those of the subspecies contributing the larger number of individuals to these mixed flocks. During HUNT, feeding flocks of Taverner's and mixed Taverner's (0-10% dusky and 11-50% dusky, respectively) were associated with large feeding flocks (Figure 4), large fields (Figure 5), and fields located far from Sturgeon Lake (Figure 6) more frequently than expected ($\underline{P}$ < 0.001, all variables). Conversely, feeding flocks of duskys and mixed dusky

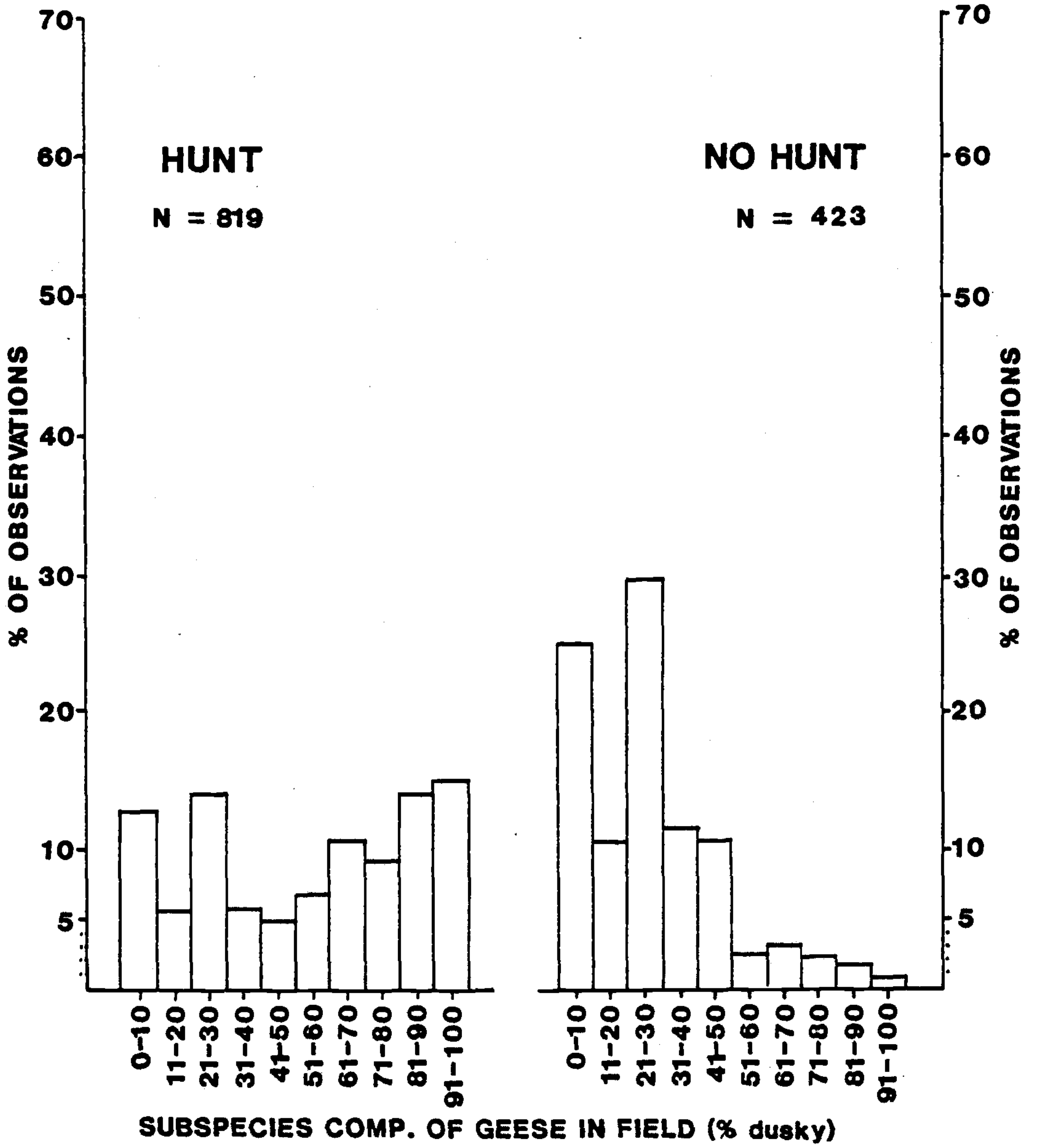


Figure 3. Frequency of observations of feeding flocks of Canada geese according to subspecies composition (proportion dusky and Taverner's) during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

Table 3. Means for selected variables associated with feeding flocks of dusky (91-100% dusky) and Taverner's (90-100% Taverner's) Canada geese observed during waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

Variable	Subspecies	N	$\bar{x}$	SD	t	P
Number of Geese in Field	Taverner's	109	2394	2280	9.98	<0.001
	Dusky	121	308	273		
Field Size (ha)	Taverner's	109	41.0	19.2	3.92	<0.001
	Dusky	121	31.8	16.5		
Lake Distance (m)	Taverner's	109	1946	804	12.21	<0.001
	Dusky	121	771	654		

Table 4. Means for selected variables associated with feeding flocks of Taverner's (90-100% Taverner's) Canada geese observed during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

Variable	Season	N	$\bar{x}$	SD	t	P
Number of Geese in Field	HUNT	109	2394	2280	6.83	<0.001
	NOHUNT	97	770	556		
Field Size (ha)	HUNT	109	41.0	19.2	7.29	<0.001
	NOHUNT	106	22.9	17.2		

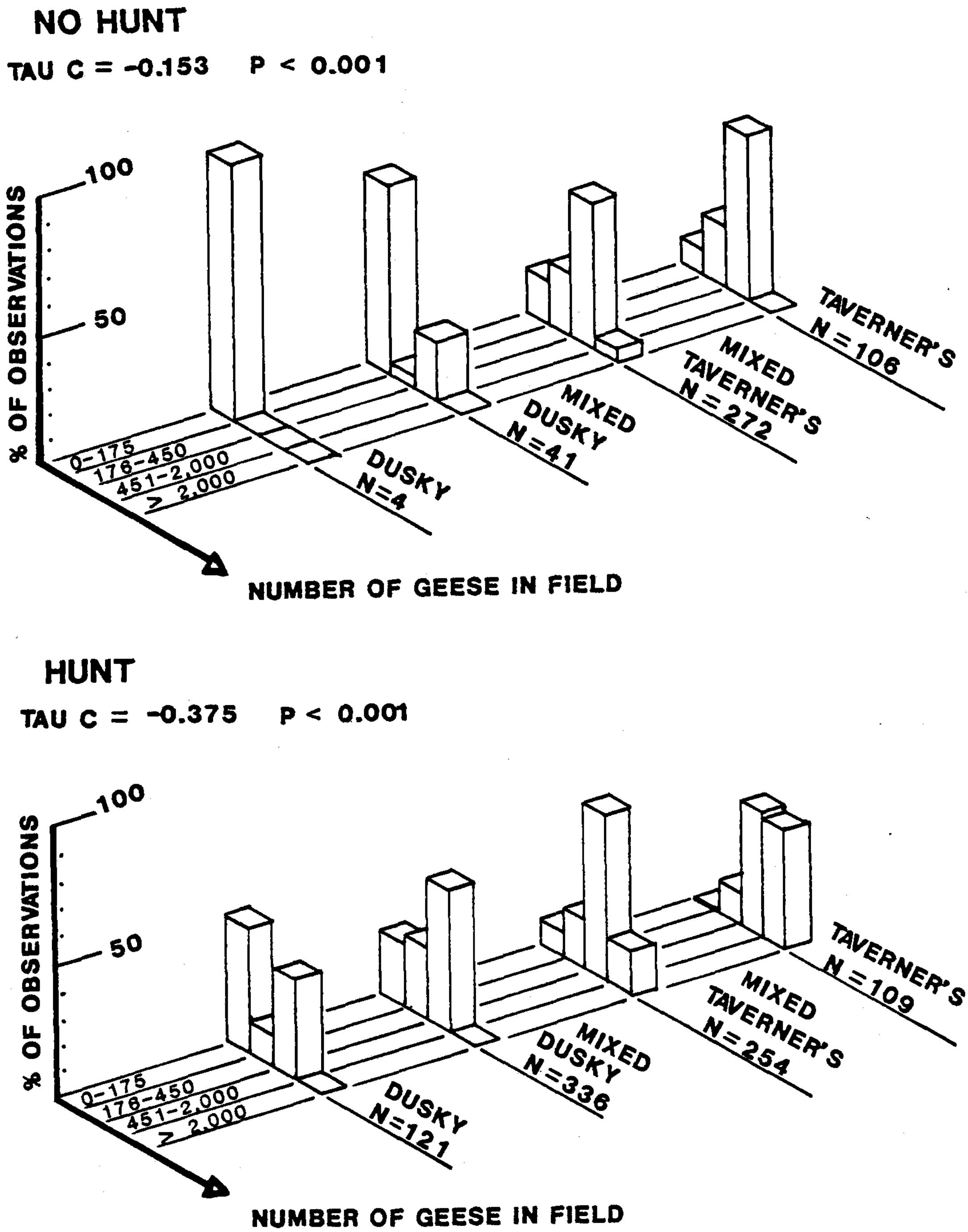
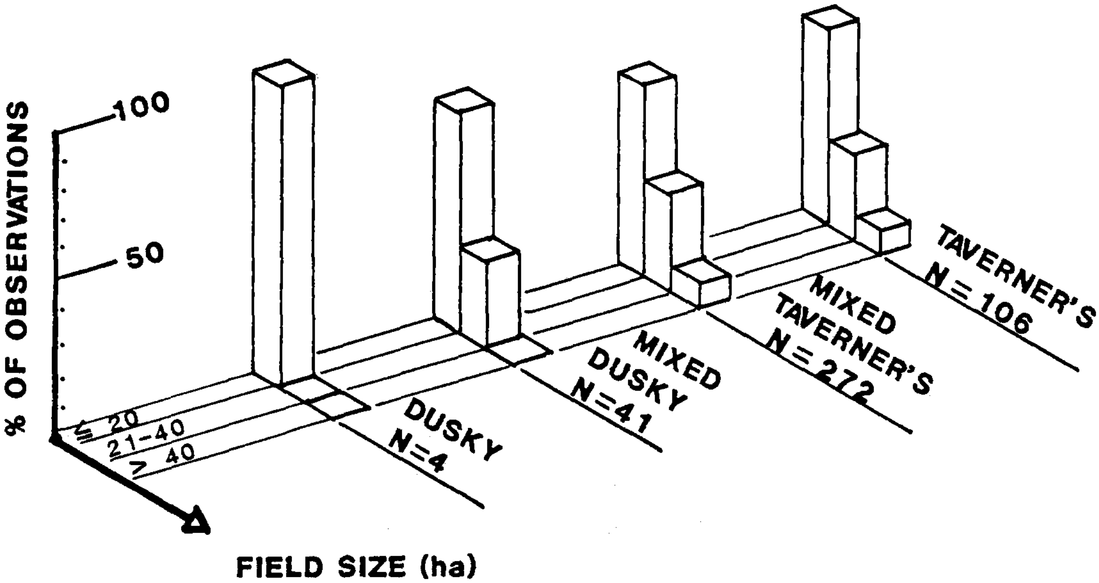


Figure 4. Frequency distribution of feeding flocks of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 4 size categories of the number of geese in a field. Dusky = flocks of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

NO HUNT

TAU C = -0.036 P = 0.150



HUNT

TAU C = -0.250 P < 0.001

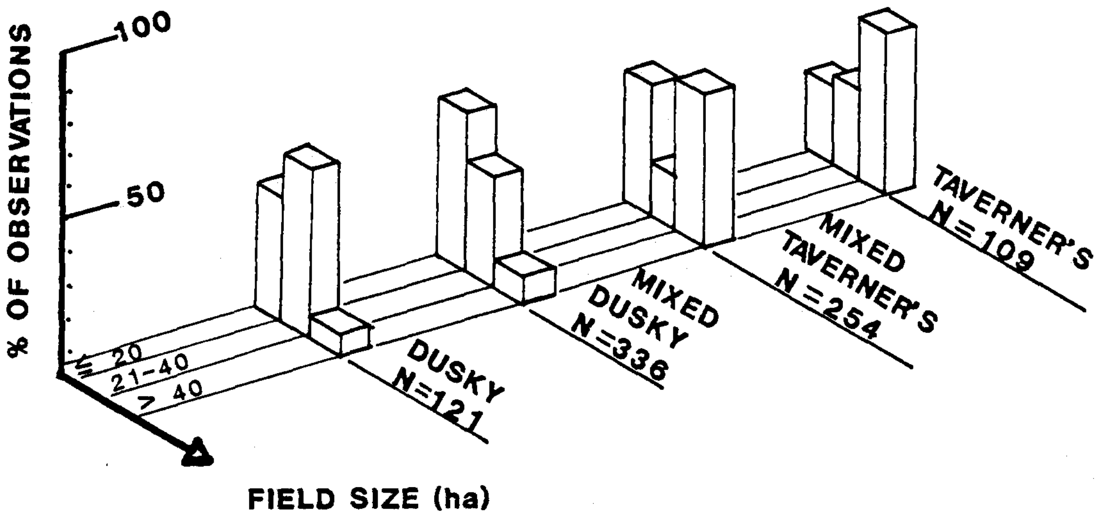


Figure 5. Frequency distribution of feeding flocks of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 3 size categories of fields. Dusky = flocks of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

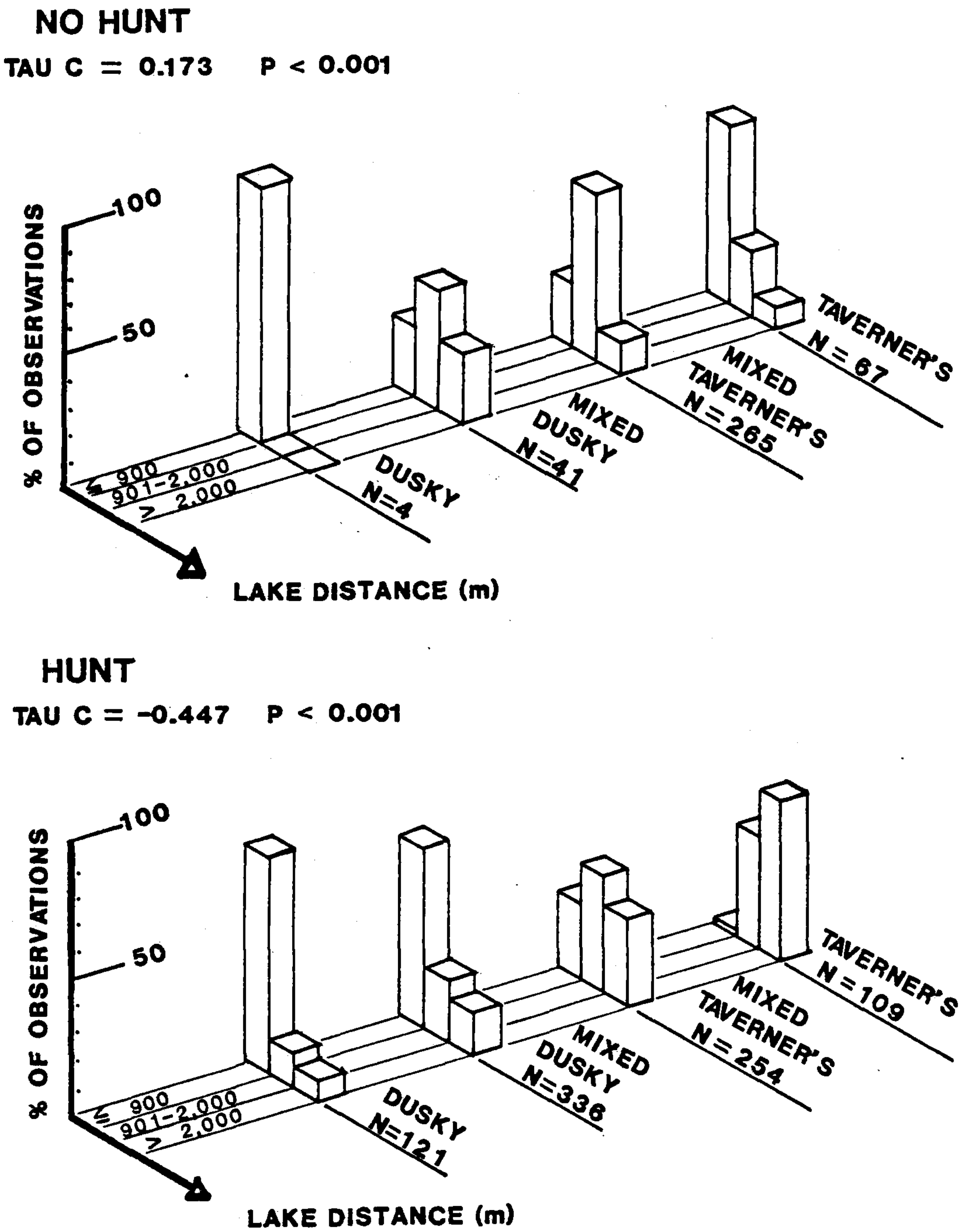


Figure 6. Frequency distribution of feeding flocks of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 3 categories of the distance from Sturgeon Lake. Dusky = flocks of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

(91-100% dusky and 51-90% dusky, respectively) were associated with small feeding flocks, small fields, and fields located close to Sturgeon Lake (Figures 4 through 6) more frequently than expected ($\underline{P} < 0.001$, all variables).

The negative relationship between subspecies composition (as % dusky) and the number of geese in a field diminished following hunting season (Tau C for HUNT = -0.375, Tau C for NOHUNT = -0.153, Figure 4). After hunting ceased, all feeding flocks were observed most frequently in small fields (63%, $\underline{N}$ = 423, ≤ 20 ha), close to Sturgeon Lake (87%, $\underline{N}$ = 377, ≤ 2,000 m, Figure 5 and 6). Danger distance was not strongly associated with subspecies composition of feeding flocks during HUNT (Tau C for HUNT = -0.058). Following hunting, all feeding flocks except those composed of 91-100% dusky ($\underline{N}$ = 4) frequented fields close to danger (70%, $\underline{N}$ = 419, ≤ 200 m, Figure 7).

During HUNT, approximately 2% ($\underline{N}$ = 109) of the feeding flocks of Taverner's and 80% ($\underline{N}$ = 121) of the flocks of duskys were observed in fields on state owned land. Following hunting, all feeding flocks of geese except those composed of 91-100% dusky ($\underline{N}$ = 4) were observed most frequently (91%, $\underline{N}$ = 419) in fields on privately owned land (Figure 8).

I could determine no patterns for the association between crop and subspecies composition of feeding flocks or for the amount of water in a field and subspecies composition of feeding flocks during either season (Appendix Figures 1 and 2).

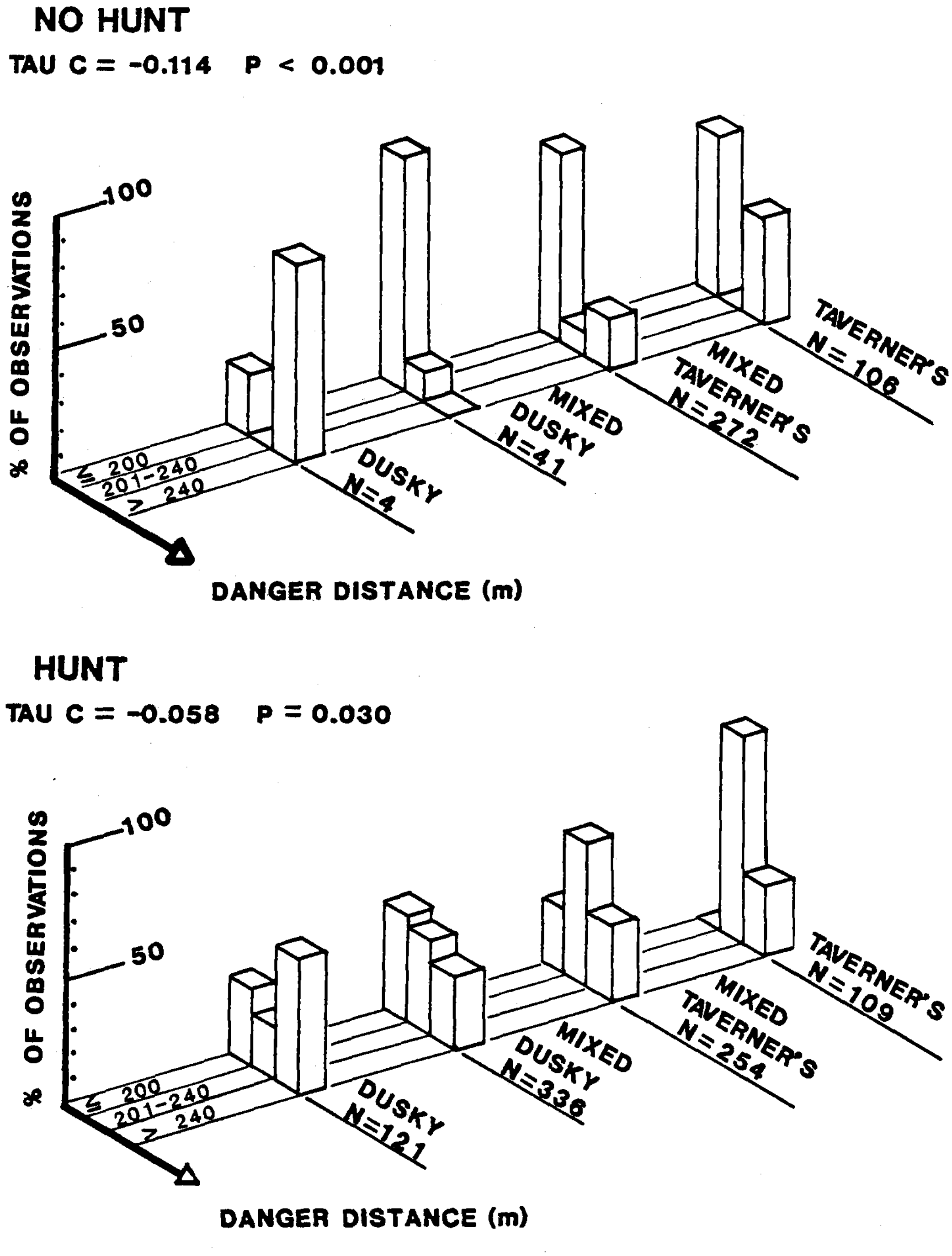


Figure 7. Frequency distribution of feeding flocks of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 3 categories of the distance from danger. Dusky = flocks of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

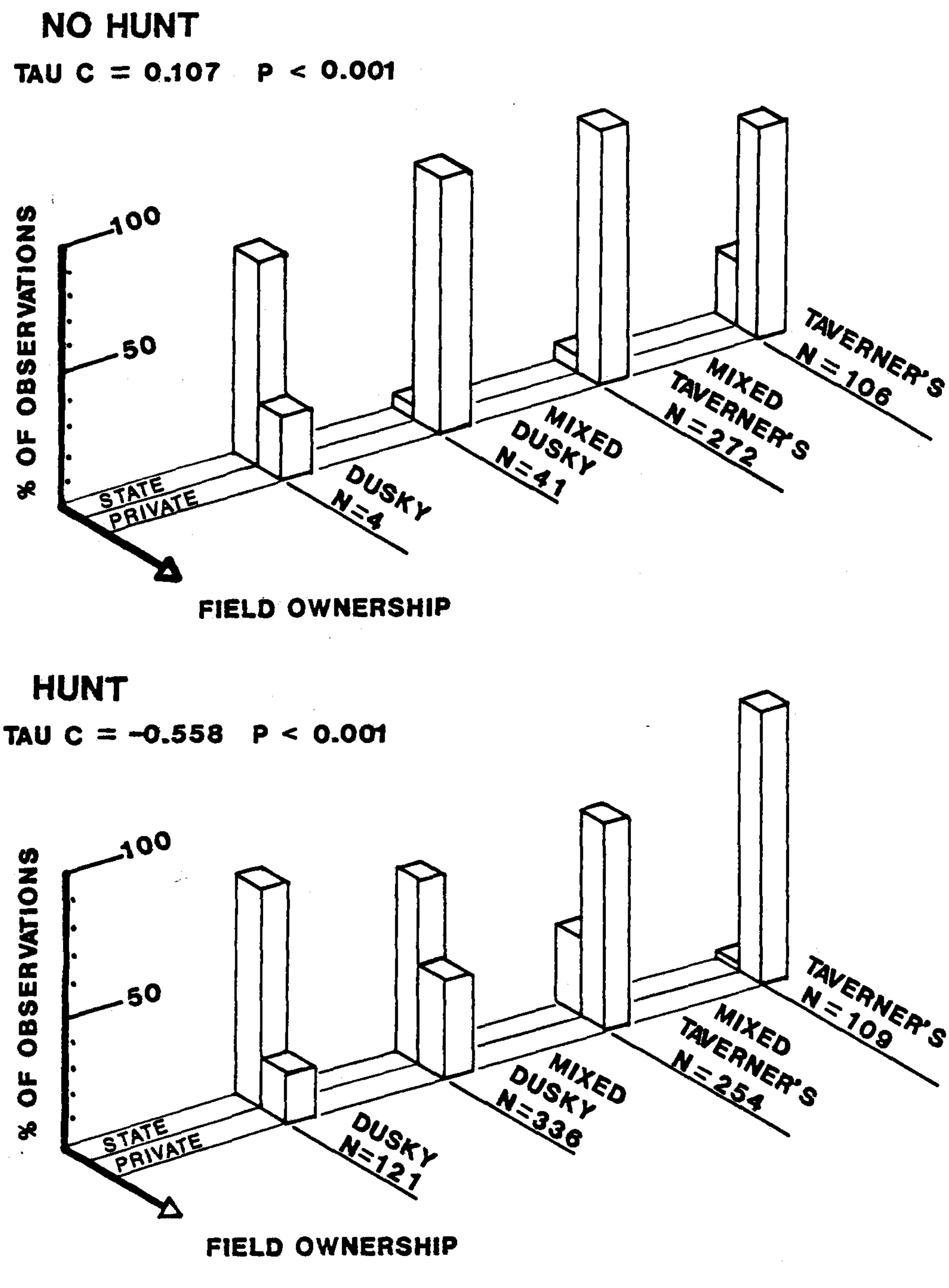


Figure 8. Frequency distribution of feeding flocks of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 2 categories of field ownership. Dusky = flocks of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

Skeins: Dusky vs. Taverner's

On the average, skeins of Taverner's during HUNT contained more geese, started their feeding field approach from higher elevations, circled more times before landing, and took longer to land than skeins of duskys (P < 0.001, all variables, Table 5). Skeins of Taverner's approached feeding fields containing a larger mean number of geese, with a larger mean field size, located farther from Sturgeon Lake than skeins of duskys (P < 0.001, all variables, Table 5).

There was a significant difference (P < 0.001) in subspecies composition of geese in fields approached by skeins of Taverner's and by skeins of duskys during HUNT (Table 5). Skeins of duskys approached feeding flocks numerically dominated by duskys (HUNT $\bar{x}$ = 72% dusky, N = 353), while skeins of Taverner's approached feeding flocks numerically dominated by Taverner's (HUNT $\bar{x}$ = 64% Taverner's, N = 303).

Following the hunting season, differences between subspecies were similar to those noted for hunting season, but the magnitude of these differences was less (Table 6). This reduction in the differences between subspecies from HUNT to NOHUNT resulted primarily from the reduction of mean values for the variables associated with skeins of Taverner's. The means for the number and subspecies composition of geese in a field, approach elevation, time interval from approach to landing, and field size associated with skeins of Taverner's were significantly smaller during NOHUNT than during HUNT (P < 0.001, all variables, Table 7).

Table 5. Means for selected variables associated with skeins of dusky (91-100% dusky) and Taverner's (90-100% Taverner's) Canada geese observed during waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

Variable	Subspecies	N	$\bar{x}$	SD	t	P
Number of Geese in Field	Taverner's Dusky	309 359	1263 525	1612 572	8.10	<0.001
Approach Elevation (m)	Taverner's Dusky	324 361	121 65	83 56	10.33	<0.001
Number of Geese in Skein	Taverner's Dusky	331 382	33 11	121 17	3.62	<0.001
Number of Circles	Taverner's Dusky	324 361	1.6 0.8	1.7 1.0	7.84	<0.001
Time Interval to First Landing (sec)	Taverner's Dusky	324 361	84.5 45.6	64.4 39.2	9.67	<0.001
Time Interval to Last Landing (sec)	Taverner's Dusky	323 361	96.7 47.6	72.6 41.6	10.97	<0.001
Field Size (ha)	Taverner's Dusky	331 382	36.9 29.0	22.0 19.3	5.10	<0.001
Lake Distance (m)	Taverner's Dusky	331 382	1574 975	932 800	9.24	<0.001
Subspecies Composition of Geese in Field (% dusky)	Taverner's Dusky	303 353	35.5 72.5	27.6 24.3	-18.28	<0.001

Table 6. Means for selected variables associated with skeins of dusky (91-100% dusky) and Taverner's (90-100% Taverner's) Canada geese observed after waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

Variable	Subspecies	N	x	SD	t	P
Number of Geese in Field	Taverner's	279	681	591	1.46	0.146
	Dusky	76	608	742		
Approach Elevation (m)	Taverner's	220	84	39	2.07	0.039
	Dusky	58	70	35		
Number of Geese in Skein	Taverner's	319	20	45	3.11	0.002
	Dusky	88	7	6		
Number of Circles	Taverner's	220	1.5	1.3	3.22	0.001
	Dusky	58	1.0	0.8		
Time Interval to First Landing (sec)	Taverner's	220	50.0	34.4	3.14	0.002
	Dusky	58	37.4	19.8		
Time Interval to Last Landing (sec)	Taverner's	220	63.6	46.9	4.42	<0.001
	Dusky	58	39.5	22.7		
Field Size (ha)	Taverner's	319	21.9	18.3	2.16	0.032
	Dusky	88	17.6	12.1		
Lake Distance (m)	Taverner's	279	1431	745	1.75	0.081
	Dusky	82	1272	638		
Subspecies Composition of Geese in Field (% dusky)	Taverner's	279	25.2	20.5	-7.61	<0.001
	Dusky	76	35.8	18.0		

Table 7. Means for selected variables associated with skeins of Taverner's (90-100% Taverner's) Canada geese observed during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

Variable	Season	N	$\bar{x}$	SD	t	P
Number of Geese in Field	HUNT	309	1263	1612	5.69	<0.001
	NOHUNT	279	681	591		
Approach Elevation (m)	HUNT	324	121	83	6.11	<0.001
	NOHUNT	220	84	39		
Number of Geese in Skein	HUNT	331	33	121	1.88	0.061
	NOHUNT	319	20	45		
Number of Circles	HUNT	324	1.6	1.7	0.51	0.610
	NOHUNT	220	1.5	1.3		
Time Interval to First Landing (sec)	HUNT	324	84.5	64.4	7.15	<0.001
	NOHUNT	220	50.6	34.4		
Time Interval to Last Landing (sec)	HUNT	323	96.7	72.6	5.95	<0.001
	NOHUNT	220	63.6	46.7		
Field Size (ha)	HUNT	331	36.9	22.0	9.45	<0.001
	NOHUNT	319	21.9	18.3		
Subspecies Composition of Geese in Field (% dusky)	HUNT	303	35.5	27.6	5.08	<0.001
	NOHUNT	279	25.2	20.5		

Differences between the seasons were not so noteable for skeins of duskys as they were for skeins of Taverner's. Skeins of duskys observed during NOHUNT did approach smaller fields, containing a smaller proportion of duskys in the feeding flock than skeins of duskys observed during HUNT ($P < 0.001$, both variables), but the means for other variables associated with skeins of duskys were similar for both seasons (Table 8). The decreased number of duskys using Sauvie Island after the hunting season probably accounts for the shift in subspecies composition of geese in fields approached by skeins of duskys.

Skeins: All Categories of Subspecies Composition

Comparisons across all categories of subspecies composition of skeins yielded essentially the same results as comparisons based on the two extreme categories (e.g. 0-10% dusky and 91-100% dusky). During HUNT, skeins of Taverner's and mixed Taverner's were associated more frequently than expected ($P < 0.001$, all variables) with large feeding and flying groups, high approach elevations, many circles before landing, long mean time intervals from approach to landing, large fields, and fields located far from Sturgeon Lake (Figures 9 through 15). Skeins of duskys and mixed dusky were associated more frequently than expected ($P < 0.001$, all variables) with small feeding and flying groups, low approach elevations, few circles before landing, small mean time intervals from approach to landing, small fields, and fields located close to Sturgeon Lake (Figures 9 through 15).

Table 8. Means for selected variables associated with skeins of dusky (91-100% dusky) Canada geese observed during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

Variable	Season	N	$\bar{x}$	SD	t	P
Number of Geese in Field	HUNT	359	524	572	-1.10	0.273
	NOHUNT	76	608	742		
Approach Elevation (m)	HUNT	361	65	56	-0.63	0.532
	NOHUNT	58	70	35		
Number of Geese in Skein	HUNT	382	11	17	2.29	0.022
	NOHUNT	88	7	6		
Number of Circles	HUNT	361	0.8	1.0	-1.17	0.241
	NOHUNT	58	1.0	0.8		
Time Interval to First Landing (sec)	HUNT	361	45.6	39.2	1.56	0.119
	NOHUNT	58	37.4	19.8		
Time Interval to Last Landing (sec)	HUNT	361	47.6	41.6	1.46	0.144
	NOHUNT	58	39.5	22.7		
Field Size (ha)	HUNT	382	29.0	19.3	5.34	<0.001
	NOHUNT	88	17.6	12.1		
Subspecies Composition of Geese in Field (% dusky)	HUNT	353	72.5	24.3	12.48	<0.001
	NOHUNT	76	35.8	17.3		

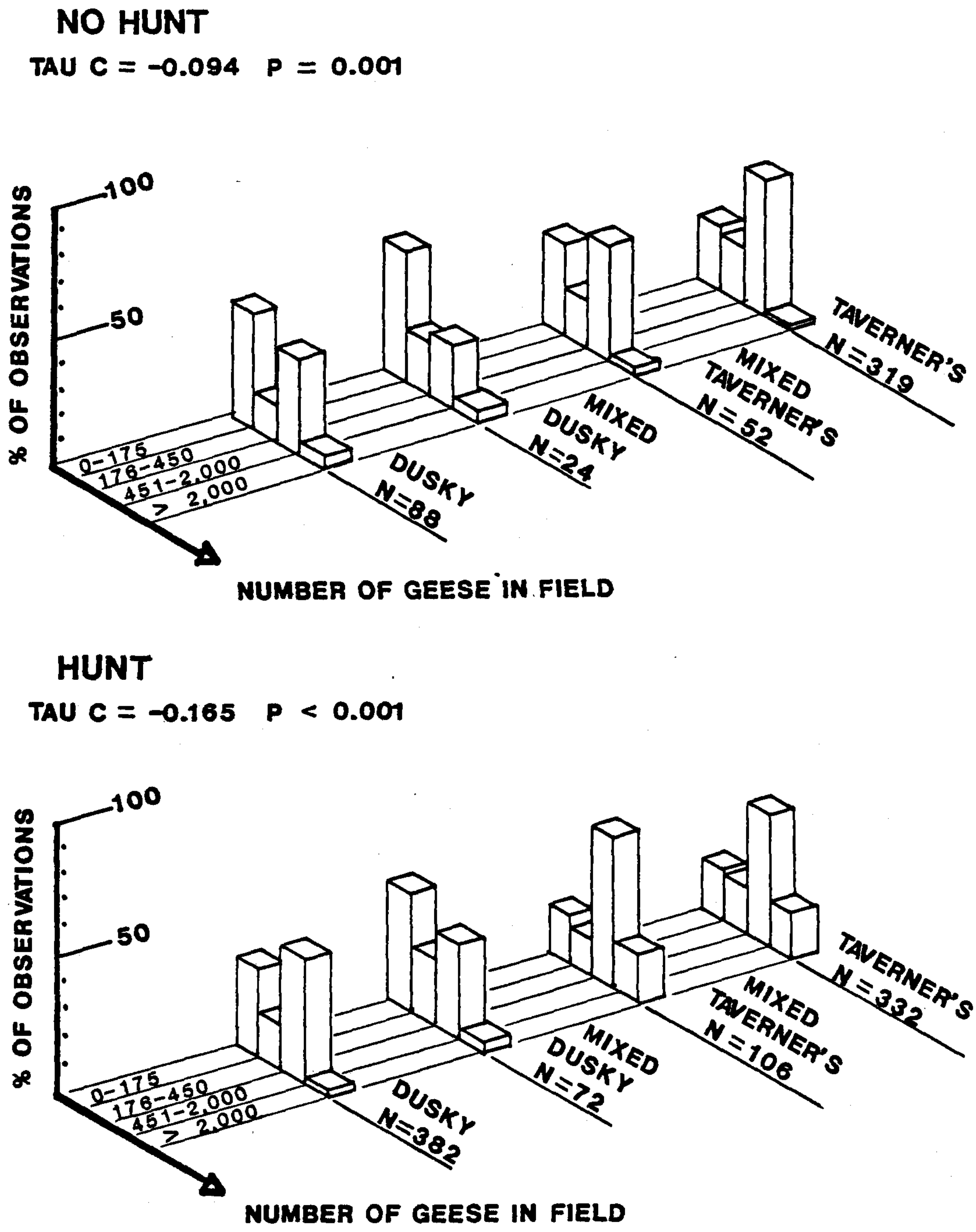
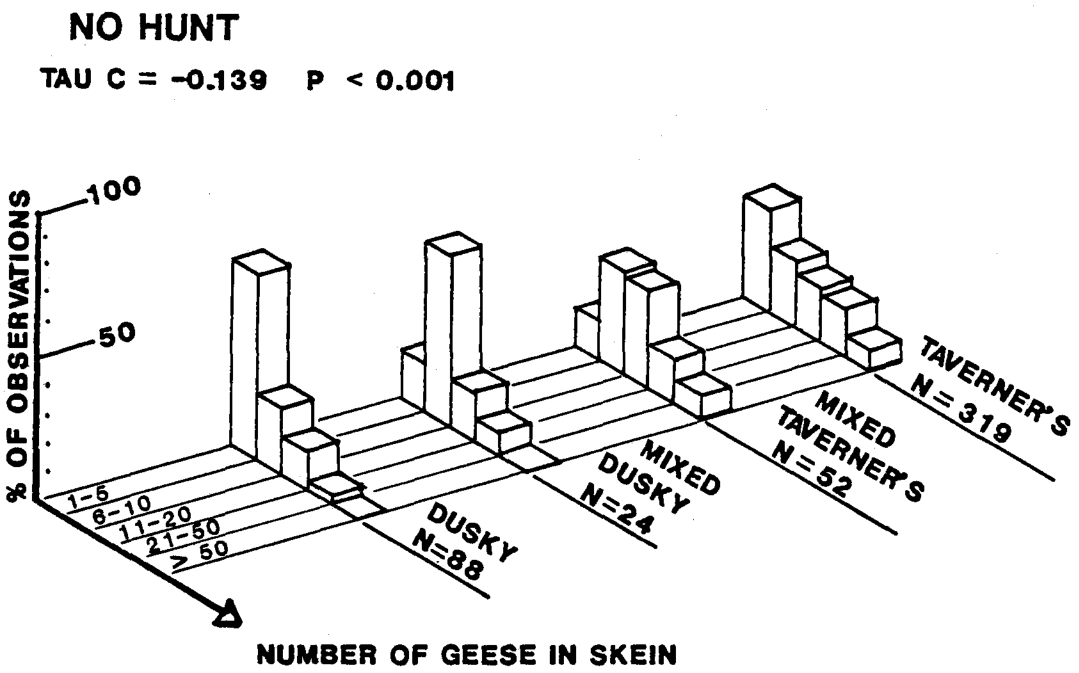


Figure 9. Frequency distribution of skeins of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 4 size categories of the number of geese in the field. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.



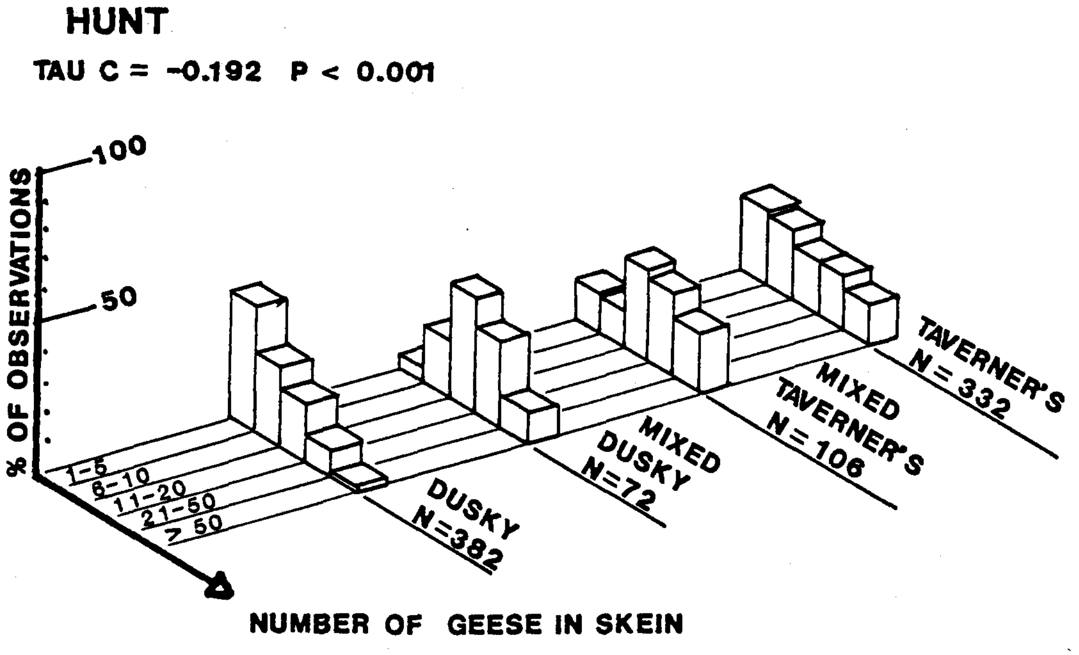
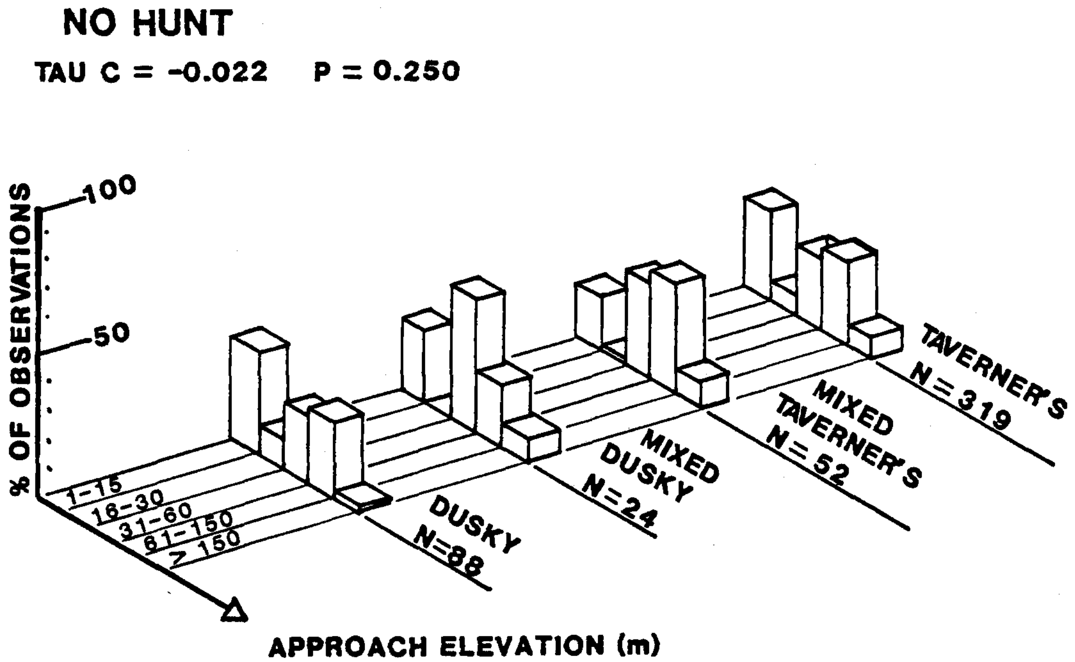


Figure 10. Frequency distribution of skeins of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 5 size categories of skeins. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.



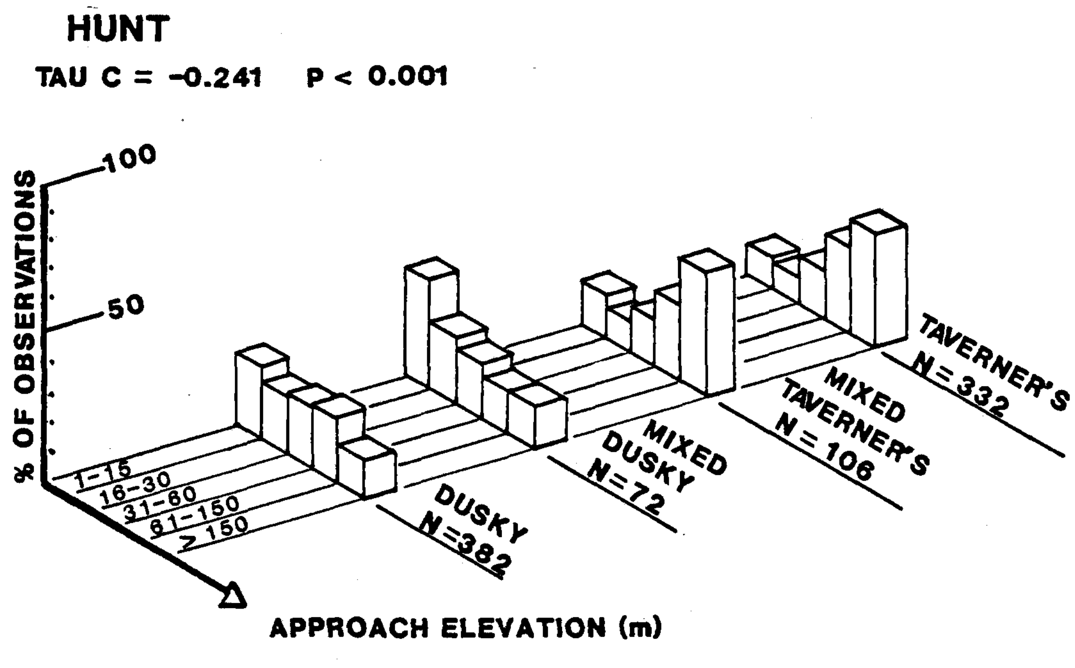


Figure 11. Frequency distribution of skeins of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 5 categories of approach elevation. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

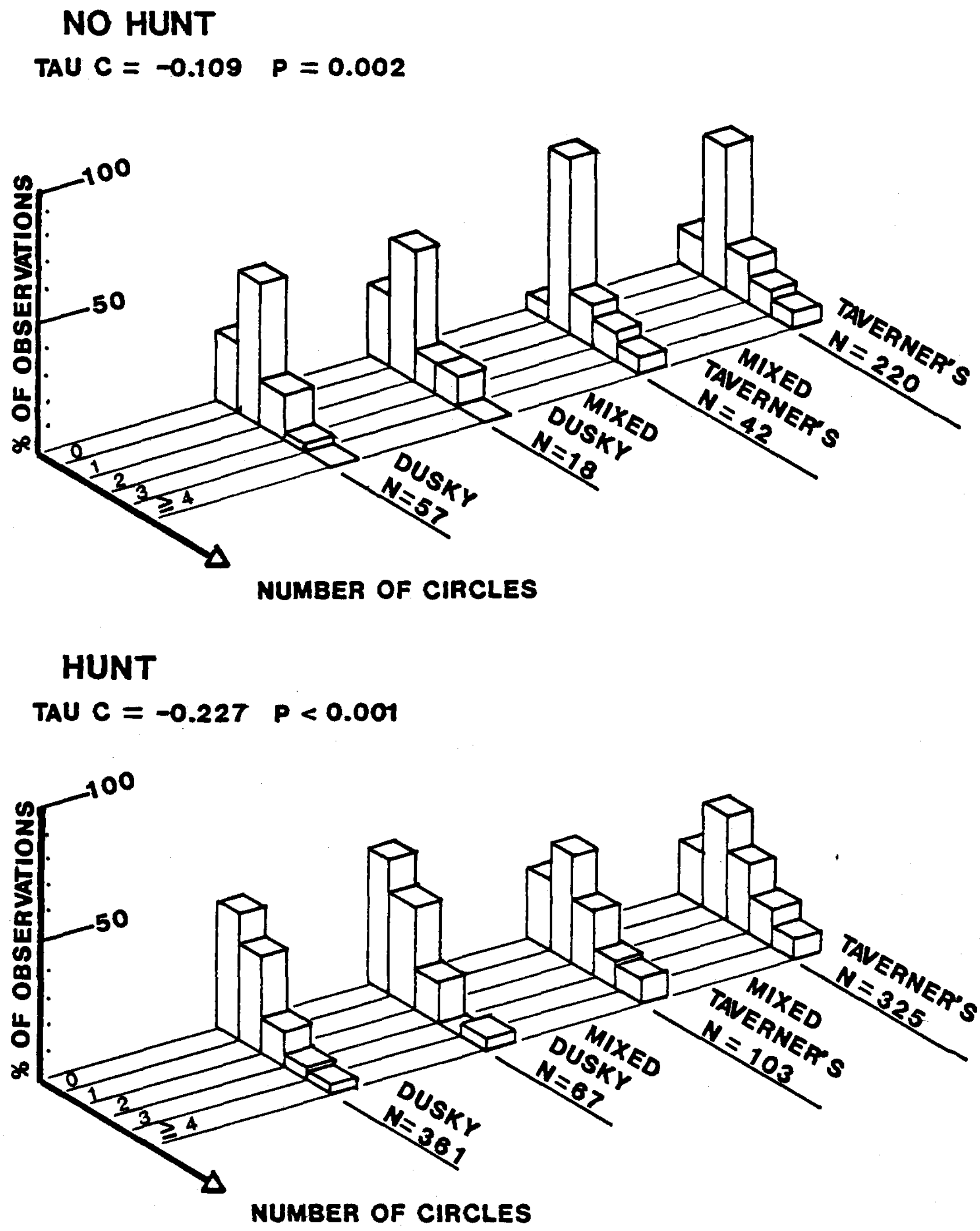
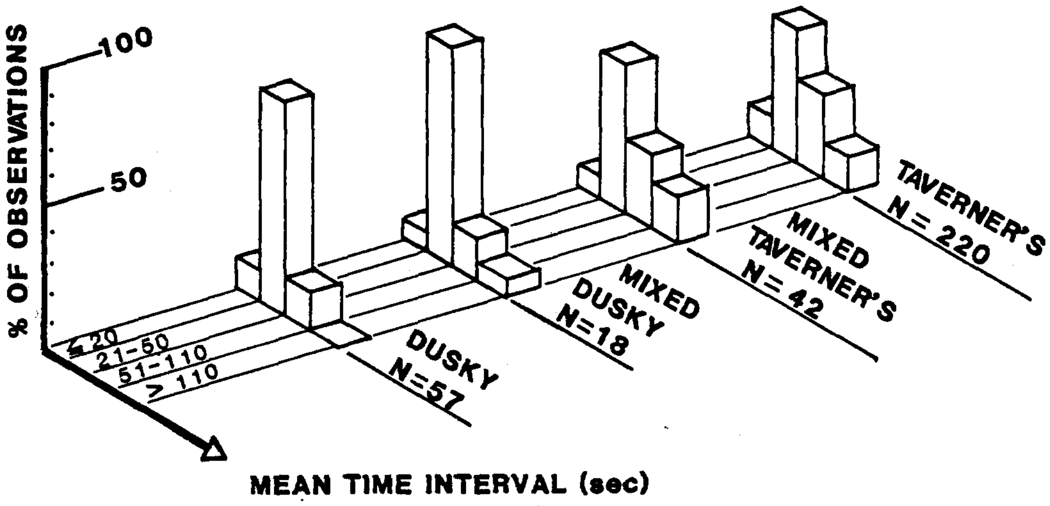


Figure 12. Frequency distribution of skeins of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 5 categories of the number of circles before landing. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

NO HUNT

TAU C = -0.116 P = 0.003



HUNT

TAU C = -0.292 P < 0.001

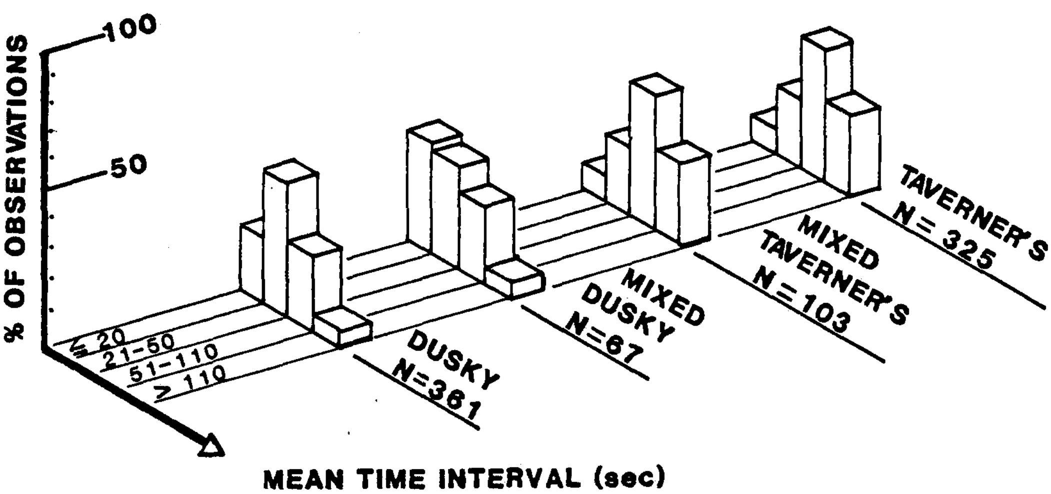
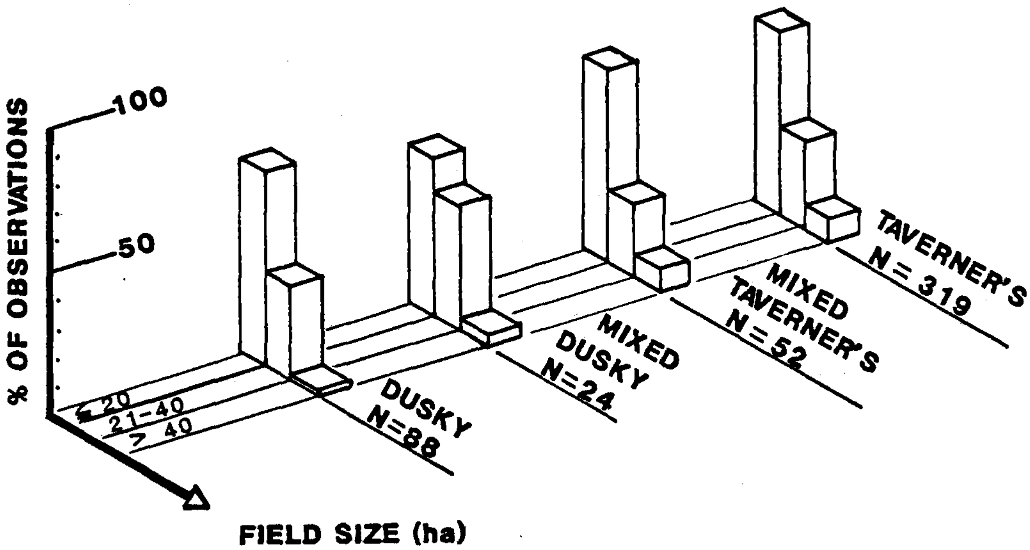


Figure 13. Frequency distribution of skeins of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 4 categories of the mean time interval from approach to landing. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

NO HUNT

TAU C = -0.039 P = 0.119



HUNT

TAU C = -0.192 P < 0.001

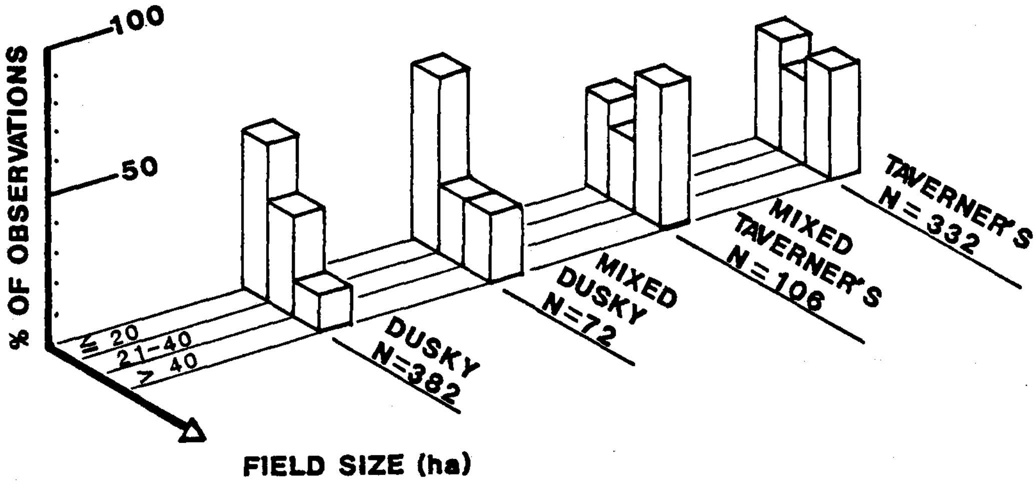
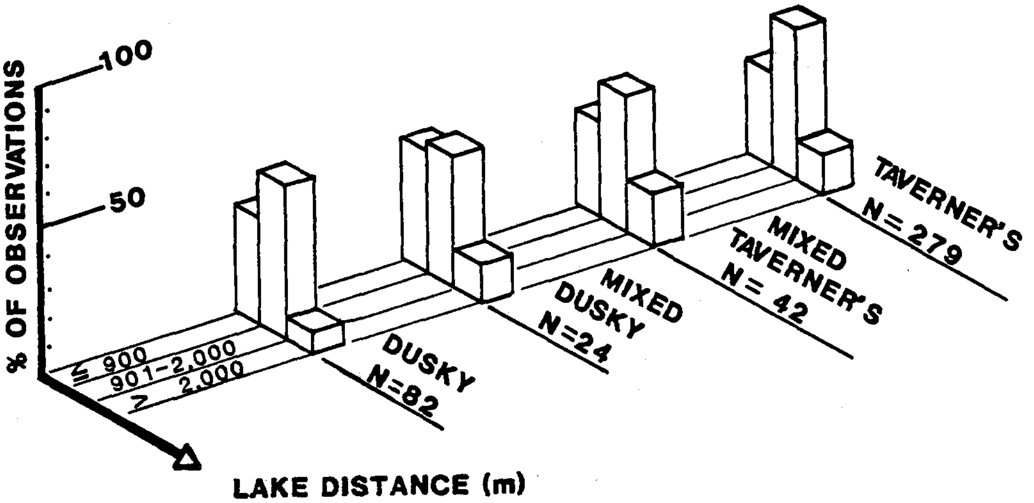


Figure 14. Frequency distribution of skeins of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 3 size categories of fields. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

NO HUNT

TAU C = −0.042 P = 0.129



HUNT

TAU C = −0.292 P < 0.001

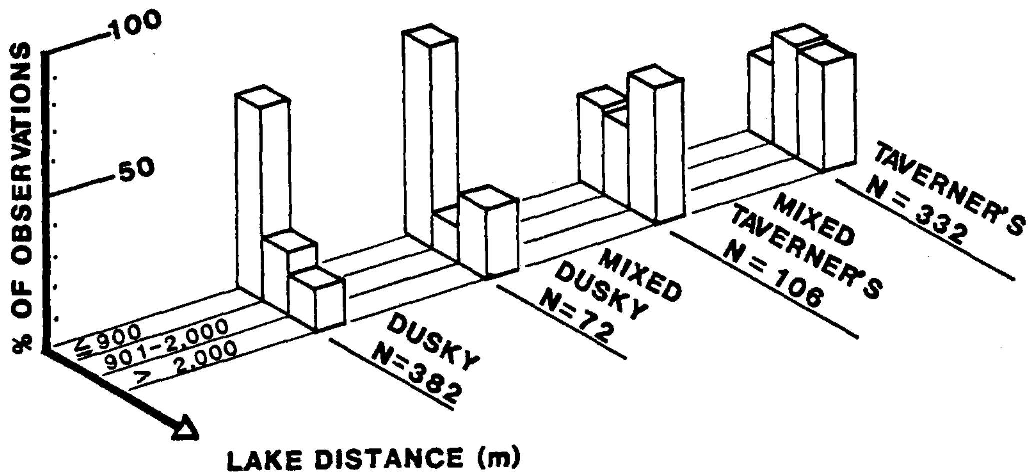


Figure 15. Frequency distribution of skeins of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 3 categories of the distance from Sturgeon Lake. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

Following hunting, the patterns of association between subspecies composition of skeins and study variables were similar to those described from HUNT data. However, these patterns of association were generally stronger during HUNT than during NOHUNT (Figures 9 through 15).

I could determine no patterns for the association between subspecies composition of skeins and danger distance during either season (HUNT *P* = 0.066, NOHUNT *P* = 0.039, Appendix Figure 3). All skeins observed during NOHUNT (*N* = 483) approached fields close to danger ($\leq$ 200 m) more frequently (68%) than they approached fields far from danger (> 200 m).

In approaching skeins of all subspecies compositions except those designated Taverner's, a dusky Canada goose was the first bird to land more frequently than expected (*P* < 0.001, both seasons, Figure 16). A Taverner's Canada goose was the last bird to land more frequently than expected (*P* < 0.001, both seasons) out of all skeins except those designated duskys (Figure 17).

During hunting season, skeins of Taverner's and mixed Taverner's approached fields on privately owned land more frequently than expected (*P* < 0.001), while skeins of duskys and mixed dusky approached fields on state owned land more frequently than expected (*P* < 0.001). Following hunting, all skeins approached fields on privately owned land most frequently (90%, *N* = 483, Figure 18).

No patterns of association between subspecies composition of skeins and crop or subspecies composition of skeins and the amount of water visible in a field were detected for either season (Appendix

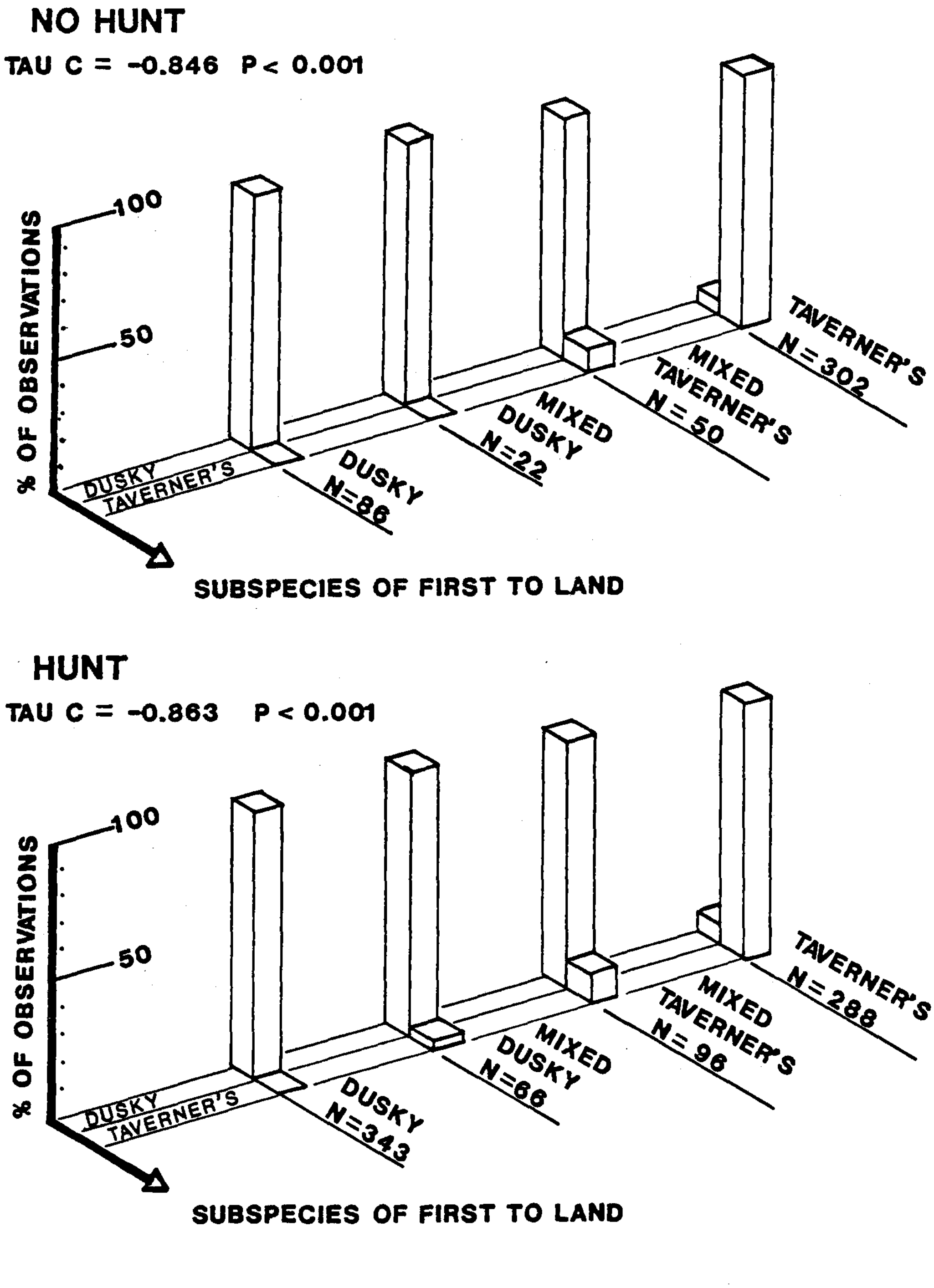


Figure 16. Frequency distribution of skeins of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 2 categories of the subspecies of goose to land first. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

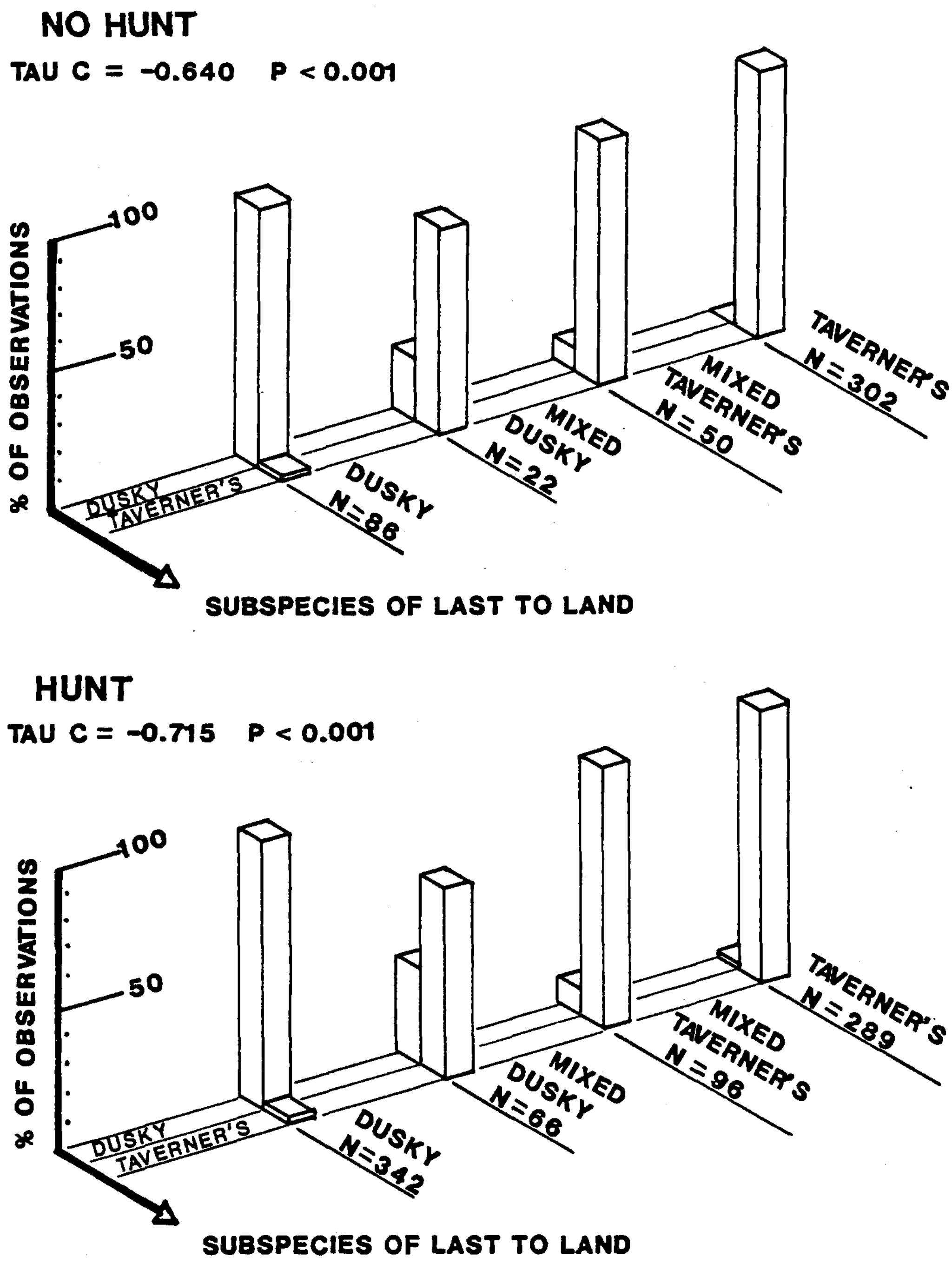


Figure 17. Frequency distribution of skeins of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 2 categories of the subspecies of goose to land last. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

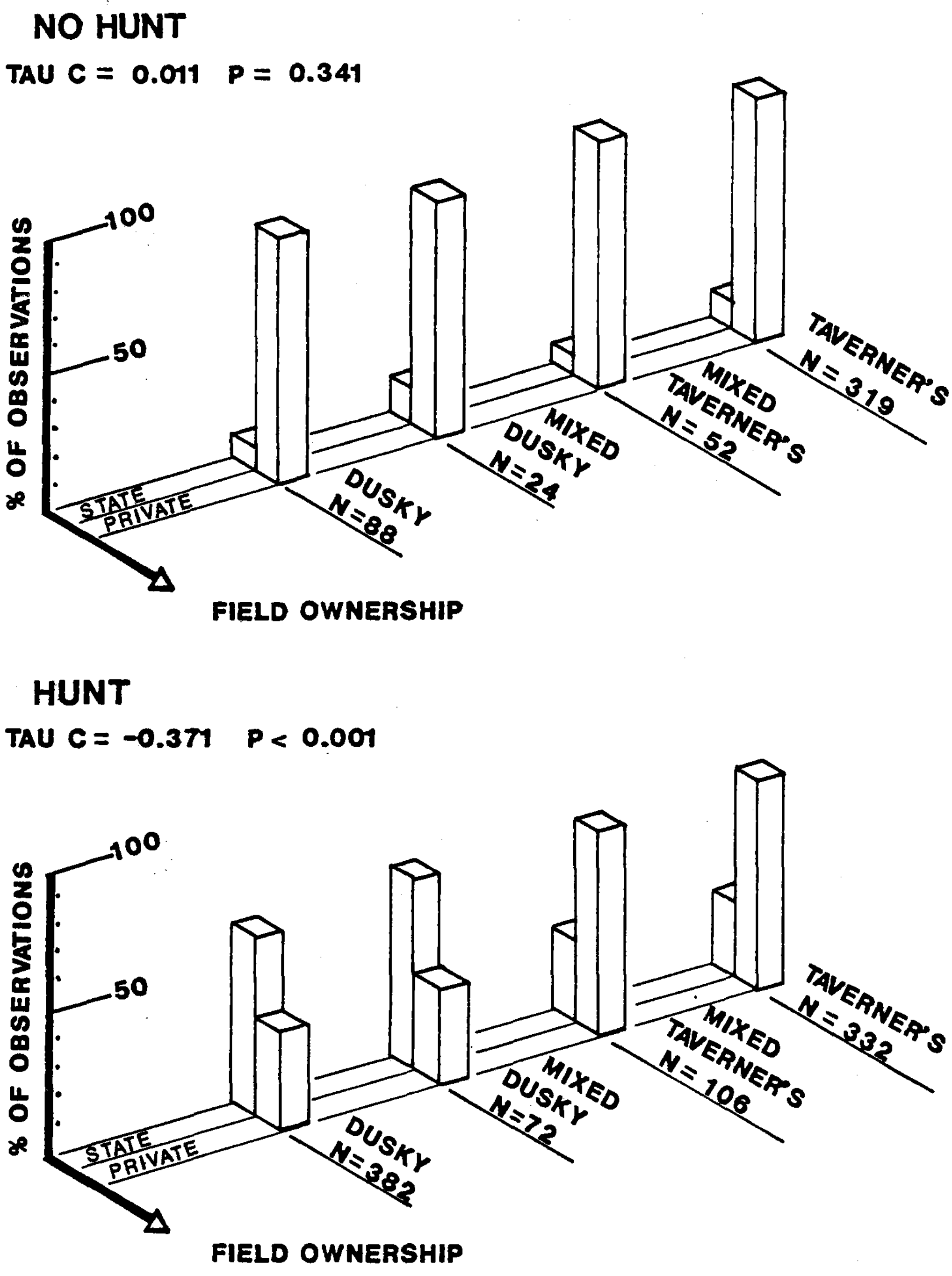


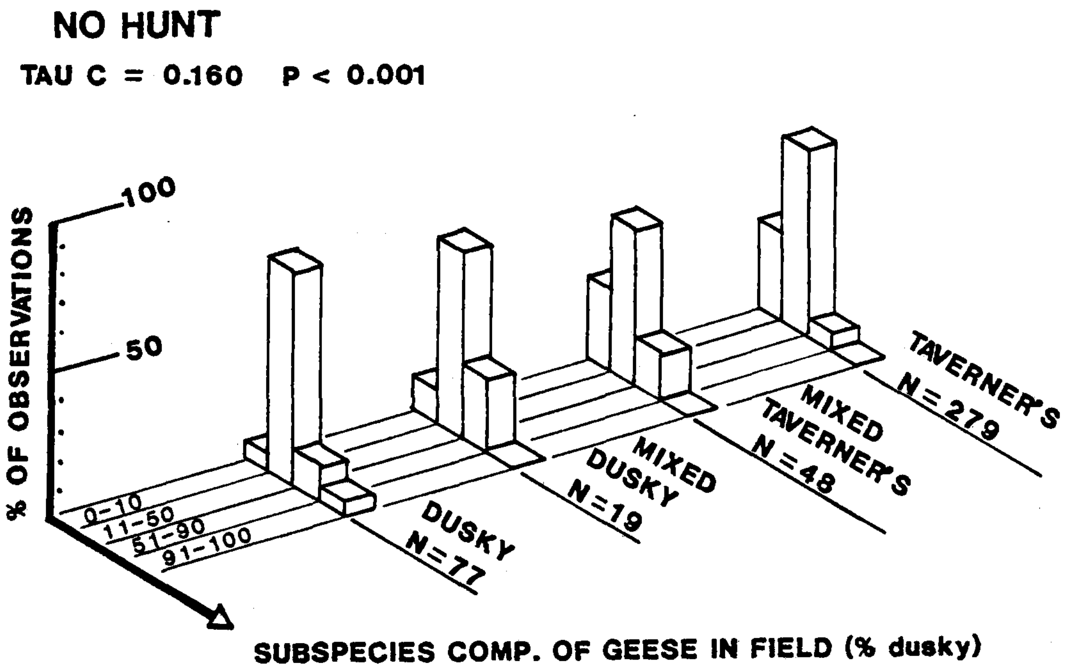
Figure 18. Frequency distribution of skeins of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 2 categories of field ownership. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

Figures 4 and 5). During hunting season, all skeins approached fields classified as mixed grains more frequently (46%, _N_ = 892) than they approached fields of other crop types.

During hunting season, skeins of Taverner's and mixed Taverner's (_N_ = 401) approached feeding flocks of Taverner's and mixed Taverner's most frequently (71%) and skeins of duskys and mixed dusky (_N_ = 418) approached feeding flocks of duskys and mixed dusky most frequently (81%). Following hunting, all skeins approached feeding flocks of mixed Taverner's more frequently (65%, _N_ = 423) than feeding flocks of other subspecies compositions (Figure 19). It should be noted, however, that relatively few (_N_ = 45) feeding flocks of duskys and mixed dusky were observed in the study area following the hunting season.

Interactions Among Variables

Multi-factor contingency table analysis indicated that the observed univariate associations between subspecies composition of skeins and other study variables were influenced by interactions among study variables. Close to Sturgeon Lake (≤ 900 m), approach elevation was not significantly associated (_P_ = 0.391) with subspecies composition of skeins for HUNT data. Farther from the lake (> 900 m), skeins of Taverner's and mixed Taverner's started their approach from high elevations more frequently than expected (_P_ < 0.001), while duskys and mixed dusky started their approach from low elevations more frequently than expected (_P_ < 0.001, Table 9). When the effect of lake distance on field size was accounted for, the association between field size and subspecies composition of skeins was significant (_P_ <



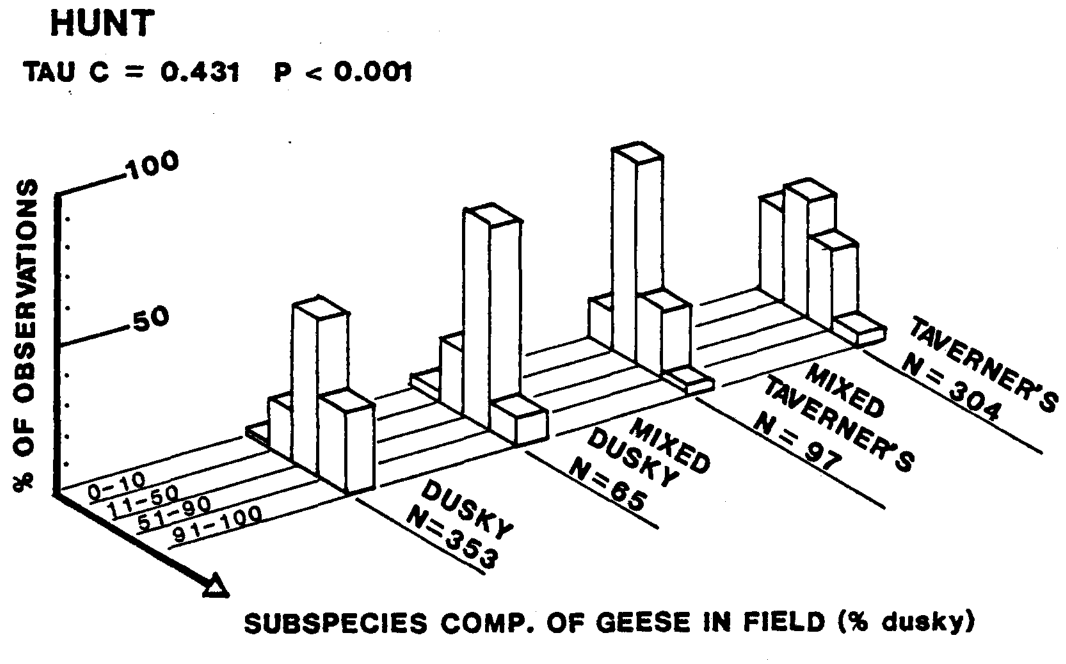


Figure 19. Frequency distribution of skeins of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 4 categories of subspecies composition of feeding flocks. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

Table 9. Effects of selected control variables on the associations between subspecies composition of Canada geese (as % dusky) in skeins and variables measuring goose behavior and field use during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

Column and Row Variables from Contingency Tables	Control Variable & Level	HUNT			NOHUNT		
		Tau C	df	P	Tau C	df	P
Subspecies Composition	Lake Distance						
in Skein	≤ 900 m	0.010	16	0.391	-0.016	12	0.397
by	901-2,000 m	-0.330	12	<0.001	-0.058	12	0.112
Approach Elevation	> 2,000 m	-0.167	12	<0.001	0.145	9	0.058
Subspecies Composition	Lake Distance						
in Skein	≤ 900 m	0.143	4	0.002	-0.014	3	0.415
by	901-2,000 m	-0.229	6	<0.001	-0.029	6	0.191
Field Size	> 2,000 m	0.010	3	0.433	-0.230	6	0.010
Subspecies Composition	Lake Distance						
in Skein	≤ 900 m	-0.081	16	0.010	-0.158	12	0.004
by	901-2,000 m	-0.160	12	0.001	-0.152	12	0.001
Number of Geese	> 2,000 m	-0.193	12	<0.001	-0.202	12	0.015
in Skein							
Subspecies Composition	Approach Elev.						
in Skein	1 - 15 m	-0.154	9	0.004			
by	16 - 30 m	-0.142	12	0.014	0.138	4	0.167
Time Interval to	31 - 60 m	-0.161	9	0.003	-0.101	9	0.038
Last Landing	61 - 150 m	-0.193	9	<0.001	-0.199	9	<0.001
	> 150 m	-0.186	9	<0.001	-0.036	6	0.399

0.001) only at medium distances from the lake (901-2,000 m) during HUNT (Table 9). At medium distances from Sturgeon Lake, 52% ($\underline{N}$ = 124) of the observed skeins of Taverner's and 91% ($\underline{N}$ = 85) of the observed skeins of duskys approached small (≤ 20 ha) fields. Large skeins (> 50 geese) contained a high proportion of Taverner's geese more frequently than expected ($\underline{P}$ ≤ 0.001) far from the lake (> 900 m) during HUNT, while no significant association ($\underline{P}$ = 0.010) between subspecies composition of skeins and the number of geese in skeins was observed for skeins approaching fields close to Sturgeon Lake (≤ 900 m, Table 9). In general, all skeins took less time to land (≤ 50 sec) at low approach elevations (≤ 60 m) during HUNT. But, over all categories of approach elevation, skeins of Taverner's were associated most frequently (72%, $\underline{N}$ = 324) with long time intervals from approach to landing (> 50 sec, Table 9).

Results from multi-factor contingency table analyses for NOHUNT data were similar to the trends described (above) for multi-factor contingency table analyses for HUNT data, but the strengths of associations among study variables during NOHUNT were less than for the same variables during HUNT (Table 9).

Multivariate Comparisons

Of the variables included in principal components analysis (Table 10), approach elevation and field size were the variables "most important" (i.e. accounting for variability in data) to skeins of Taverner's during HUNT (Factor I for Taverner's during HUNT, Table 10). Number and subspecies composition of geese in a field were the variables most important to skeins of duskys during HUNT (Factor I for

Table 10. Principal component factors and variable loadings (after Kaiser normalization) for skeins of dusky (91-100% dusky) and Taverner's (90-100% Taverner's) Canada geese observed during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

	Skeins of Taverner's				Skeins of Dusky				
	HUNT		NOHUNT		HUNT			NOHUNT	
Variable	Factor I	Factor II	Factor I	Factor II	Factor I	Factor II	Factor III	Factor I	Factor II
Number of Geese in Field	-0.132	0.635	-0.048	0.647	0.545	0.221	-0.189	0.991	-0.138
Approach Elevation	0.601	0.222	0.130	0.285	0.069	0.787	0.018	0.147	0.212
Field Ownership	0.438	0.599	0.479	0.390	0.470	0.275	-0.285	0.106	-0.663
Field Size	0.814	0.192	-0.191	0.504	0.218	0.724	-0.072	0.391	-0.064
Crop	0.467	-0.088	-0.577	-0.008	-0.040	-0.002	0.804	-0.265	0.480
Subspecies Composition of Geese in Field	-0.230	-0.750	0.711	-0.169	-0.983	-0.007	-0.200	-0.261	0.314
Eigen Value for Factor	2.063	0.860	1.126	0.932	1.917	0.948	0.751	1.544	0.598
Percent Variance Accounted for by Factor	70.6	29.4	54.7	45.3	53.0	26.2	20.8	72.1	27.9

duskys during HUNT, Table 10). Following hunting, subspecies composition of geese in a field and crop were the variables most important to Taverner's (Factor I for Taverner's during NOHUNT, Table 10), while the number of geese in a field was the most important variable to duskys (Factor I for duskys during NOHUNT, Table 10).

My interpretation of the results from principal components analysis is consistent with my interpretation of the results based on univariate analyses; dusky and Taverner's Canada geese differed in patterns of behavior and use of fields within both seasons, and there was a seasonal change in these patterns for Taverner's, but not for duskys.

The best discriminant functions derived to distinguish between dusky and Taverner's Canada geese were moderately successful in classifying actual cases with respect to subspecies identity (Tables 11 through 14). 89% (N = 230) of the data were correctly classified for feeding flocks observed during HUNT. 78% (N = 629) of skeins observed during HUNT and 78% (N = 241) of skeins observed during NOHUNT were correctly classified according to actual subspecies using these discriminant functions. However, the accuracy and success of these discriminant functions should be verified using a separate set of data from the set used to derive the functions. A discriminant function was not attempted for feeding flocks observed during NOHUNT.

Field ownership (state vs. private) contributed highly (discriminant function coefficient = 0.84) to the discrimination between feeding flocks of duskys and feeding flocks of Taverner's during the hunting season (Table 11). As was noted earlier in this

Table 11. Standardized discriminant function coefficients from "best" discriminant function derived for feeding flocks of dusky (91-100% dusky) and Taverner's (90-100% Taverner's) Canada geese observed during waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

Variable	Standardized Discriminant Function Coefficient
Number of Geese in Field	0.44
Field Ownership	0.84
Field Size	0.20

Table 12. Results of classification using the "best" discriminant function derived for feeding flocks of dusky (91-100% dusky) and Taverner's (90-100% Taverner's) Canada geese observed during waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

Actual Feeding Flock Membership	N	Predicted Membership	
		Percent Taverner's	Percent Dusky
Taverner's	109	98	2
Dusky	121	19	81

Table 13. Standardized discriminant function coefficients from "best" discriminant functions derived for skeins of dusky (91-100% dusky) and Taverner's (90-100% Taverner's) Canada geese observed during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

	Standardized Discriminant Function Coefficient	
Variable	HUNT	NOHUNT
Number of Geese in Field	0.02	0.24
Approach Elevation	-0.45	-0.30
Number of Geese in Skein	-0.12	-0.25
Field Ownership	-0.07	-0.19
Field Size	0.23	0.04
Subspecies Composition of Geese in Field	0.85	1.00

Table 14. Results of classification using the "best" discriminant functions derived for skeins of dusky (91-100% dusky) and Taverner's (90-100% Taverner's) Canada geese observed during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

Actual Skein Membership and Season	N	Predicted Membership	
		Percent Taverner's	Percent Dusky
Taverner's			
HUNT	296	72	28
NOHUNT	190	82	18
Dusky			
HUNT	333	16	84
NOHUNT	51	37	63

paper, duskys were more frequently associated with fields on state owned land (80%, *N* = 121), while Taverner's frequented fields on privately owned land (98%, *N* = 109) during the hunting season.

Approach elevation (discriminant function coefficient for HUNT = -0.45, and for NOHUNT = -0.30) and subspecies composition of geese in a field (discriminant function coefficient for HUNT = 0.85, and for NOHUNT = 1.00) were the variables that contributed the most to the best discriminant functions for skeins of geese during both seasons (Table 13).

Weather

There were no significant associations between any of the weather variables and either subspecies composition of feeding flocks or of skeins during either season ($P > 0.050$, all variables, both seasons). Weather may affect behavior and use of fields by geese (Raveling et al. 1972, Frederick and Klaas 1982), but the two subspecies that I studied were not affected differently within the range of weather conditions recorded. I could not identify subspecies of geese under all weather conditions, so data on weather variables were biased towards conditions of optimum observability for subspecies.

Time of Day

Time of day was not significantly related to subspecies composition of feeding flocks or of skeins during either season ($P >$ 0.050, both seasons). Time of day did correlate with the number of geese in a feeding field during the non-hunting season ($r = 0.702$, *N* =

424, $\underline{P}$ = 0.001), but not during the hunting season ($\underline{r}$ = 0.112, $\underline{N}$ = 836, $\underline{P}$ = 0.001). Possibly, in the absence of hunting disturbance, the number of geese in a feeding field increases as the day progresses.

I made regular, qualitative observations of goose activities at night in the vicinity of my residence on the shore of Sturgeon Lake. During the hunting season, nearly all of the geese in the study area spent the night on Sturgeon Lake. After the hunting season, many more birds spent nights in feeding fields, on other small water bodies in the vicinity, or flew back and forth between feeding fields and Sturgeon Lake. Unfortunately, I could not determine if these behaviors were associated with any particular subspecies of goose.

Disturbance

I recorded 77 disturbance events during the hunting season and 57 after hunting. Response of feeding geese to a disturbance usually progressed from vigilance (Lazarus 1978:135-136), to vocalization, and finally flight of at least some of the geese. Flight response was observed more frequently during HUNT than NOHUNT (χ^2 = 13.6, Table 15). The most frequently observed disturbances during both seasons were vehicles on roads in the vicinity of feeding fields (65% during HUNT, and 68% during NOHUNT, Table 16). There were differences in the frequency of disturbance observations on state and on privately owned land during, and between seasons (χ^2 between seasons = 29.9). During the hunting season, 78% of recorded disturbances occurred on state owned land and 22% on privately owned land. Following the hunting season, disturbances were observed on privately owned land 72% of the

Table 15. Frequency of Canada goose response type to disturbance during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

	Percent of Observations During Each Season	
Response	HUNT (N = 77)	NOHUNT (N = 57)
No Response	5	5
Vigilance and/or Vocalization	26	58
Flight	69	37

Table 16. Frequency of disturbance type to Canada geese observed during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82.

	Percent of Observations During Each Season	
Disturbance	HUNT (N = 77)	NOHUNT (N = 57)
Vehicle	65	68
Person	14	5
Aerial (eagle, helicopter, or plane)	17	19
Dog or Coyote	4	4
Loud Noise (acetylene exploder)	0	4

time and on state owned land 28% of the time. These differences between seasons probably coincide with the shift in use of fields by geese from fields on state owned land to fields on privately owned land.

No association between the number and subspecies composition of geese in a field and response to disturbance was seen. There were no significant relationships between type of disturbance and response during either season ($P > 0.050$, all variables, both seasons), although geese usually flew when they were "hazed" by bald eagles (*Haliaeetus leucocephalus*) and when a helicopter passed over them. Response to other disturbances was variable. I could discover no relationships between response to disturbance and any of the characteristics of feeding fields that I measured ($P > 0.050$, all variables, both seasons).

More geese (as a proportion of the total number of geese in the field) flew away in response to disturbance during HUNT than during NOHUNT (HUNT $\bar{x}$ = 58%, SD = 43.7, N = 77, NOHUNT $\bar{x}$ = 26%, SD = 41.7, N = 57; t between seasons = 4.23, $P < 0.001$). On the average, the geese that flew in response to a disturbance were numerically dominated by Taverner's, while duskys tended to remain in a field rather than fly. However, statistical tests for subspecific differences in flight response were not significant ($P > 0.050$, both seasons).

DISCUSSION

Crissey (1968), Kennedy and Arthur (1974), Koerner et al. (1974), Raveling (1969a, 1978a), Zicus (1981), and others discussed the management significance of identifying similarities and differences between subflocks and/or subspecies that make up large wintering aggregations of Canada geese. Similarities and differences in morphology, behavior, physiology, and ecology of partially sympatric subspecies also imply evolutionary significance (Aldrich 1963, Ratti 1980). According to Marquardt (1962), Grieb (1970), and Simpson and Jarvis (1979), differences in behavior and habitat choice between goose subspecies probably reflect adaptations to slightly different evolutionary ecologies.

In addition to geographic differences in nesting and wintering ranges (Hansen 1962, Bellrose 1976:141-164, Johnson et al. 1979), and morphometric differences (Johnson et al. 1979); dusky and Taverner's Canada geese exhibit differences in certain aspects of their winter ecology, including their distribution (Simpson and Jarvis 1979), behaviors (e.g. approach and landing, current study), and use of feeding fields (e.g. field size and location, Simpson and Jarvis 1979 and current study). Regardless of the cause or causes for differences between subspecies, these differences seem to affect the vulnerability of dusky and Taverner's Canada geese to hunting mortality in western Oregon (Simpson and Jarvis 1979) and may be involved in subspecies recognition by geese.

Hunting Vulnerability

Simpson and Jarvis (1979:232) found duskys to be approximately 2.7 times more likely to be shot during waterfowl hunting season (1976-78) than Taverner's. The relative differences in certain behaviors and use of fields between duskys and Taverner's during hunting season probably contributes to duskys' higher vulnerability. During waterfowl hunting season on Sauvie Island (1981-82), groups of Taverner's and mixed Taverner's (0-10% dusky and 11-50% dusky, respectively) generally fed and flew in numerically larger groups and utilized larger fields than groups of duskys and mixed duskys (91-100% dusky and 51-90% dusky, respectively).

I did not directly examine the relationship between group size and hunting vulnerability of individual group members. Studies involving other species of birds indicate that foraging and flying in numerically "large" groups probably facilitates detection and avoidance of predators (Lazarus 1978, 1979, Goldman 1980, Greig-Smith 1981, and others). Owens (1977:8) showed that in flocks of dark-bellied brent geese (*Branta bernicla bernicla*) numbering 6 to 400, larger flocks took flight at greater distances from approaching humans than smaller flocks ($r = 0.67$, $N = 22$, $P < 0.001$). Since hunters are probably the most important predators of adult geese (Hansen 1962, Martin 1964:70, Crissey 1968:143, Chapman et al. 1969, Bellrose 1976:143-144), detection and avoidance of hunters is obviously advantageous to individual geese. It is also generally believed that numerically large groups of waterfowl are more difficult to decoy (e.g. bring within shooting range of a "set" of decoys), and therefore more difficult to hunt successfully than numerically small groups (Taylor 1974:106, Simpson and Jarvis 1979:237).

Use of large fields by Taverner's and use of small fields by duskys on Sauvie Island may have affected their hunting vulnerability in more than one way. The mid-points of large fields on Sauvie Island were generally farther from danger than the mid-points of small fields (r = 0.578, N = 893, P = 0.001). Unless there was a blind located in a large field, or a flock of geese located near the field periphery (rare), a human hunter could only find cover a considerable distance from geese landing in large fields. Large fields were also associated with privately owned land, while small fields were associated with state owned land. Hunting efforts seemed stronger and disturbances due to hunting more frequent on state owned land than on privately owned land on Sauvie Island.

During waterfowl hunting season, skeins of Taverner's and mixed Taverner's generally started their approach to feeding fields from a higher elevation, circled more over a field before landing, and took longer to land than skeins of duskys and mixed duskys. Skeins of Taverner's and mixed Taverner's also swarmed and "whiffled" (Newton et al. 1973:113) more as they landed than skeins of duskys and mixed dusky. Although Taverner's were in the air over a field for a relatively longer period of time than duskys, their high approach elevation [66% of skeins of Taverner's and mixed Taverner's (N = 438) started approach at elevations > 60 m] kept them out of shooting range much of this time. The distracting visual effect of the numerically large, swarming skeins of Taverner's probably made them more difficult to successfully shoot than duskys.

Taverner's Canada geese were more varied and variable in their behavior and use of fields during winter than duskys. The overall range of values recorded as well as variances calculated for variables associated with groups of Taverner's were generally greater than for variables associated with groups of duskys. This suggests behavioral and perhaps ecological flexibility on the part of Taverner's, while duskys are the more traditional and habitual subspecies. Accurately predicting the behaviors and response of geese to their environment positively influences hunting success by humans (Taylor 1974). The more predictable subspecies should be easiest to hunt successfully.

Taverner's exhibited significant changes in behavior and use of fields from hunting to post-hunting season, while duskys exhibited essentially the same patterns of behavior and use of fields throughout the study. The shift in Taverner's behavior and use of fields was from patterns that could make them less vulnerable to hunting (than duskys) during waterfowl hunting season to patterns similar to those of duskys following the waterfowl hunting season. While this shift in the patterns exhibited by Taverner's may be attributable to many factors, I believe that it is associated with hunting and its cessation. Although duskys did change from feeding primarily in fields on state owned land during hunting to fields on privately owned land following hunting, duskys did not change their field approach and landing behaviors in response to hunting and its cessation. Since state owned land was probably more intensively hunted than privately owned land (alternate days vs. 1-3 days per week), the noted change in use of fields by duskys was not clearly related to the cessation of hunting.

Behavioral Segregation

Although generally allopatric during nesting (Bellrose 1976:141-164), many of the subspecies of Canada geese are at least partially sympatric during winter and early spring. The extent of intergradation between subspecies of Canada geese is not presently known. Presumably, breeding between individuals of different subspecies is rare in nature, but does occur under captive conditions. Geographic isolation during pairing and breeding probably explains the presence and maintenance of the numerous subspecies of Canada geese in North America (Martin 1964:2, Ratti 1980:861). While first-time pairing between inexperienced breeders probably occurs on the nesting ground and thus serves as a mechanism for reproductive isolation, it is unlikely that the process of pair formation takes place exclusively on subspecies-specific nesting areas.

Canada geese pair "for life," and only seek a new mate if one pair member dies (Bellrose 1976:158). There is evidence that Canada geese may form pair bonds during winter or early spring (Delacour and Mayr 1945:8-10, Hanson 1953:15, Balham 1954:62), during the nesting season (Balham 1954:62, Delacour 1954:151, Geis 1956, Martin 1964:30-33, Sherwood 1966:133-134, Raveling 1969b:316), or over a period of several seasons (Raveling 1969b:312-316) depending on the age, breeding experience, and subspecies of geese. Hunting mortality during fall and winter is the highest source of mortality for many subspecies of adult geese (Hansen 1962, Martin 1964:70, Crissey 1968: 143, Chapman et al. 1969, Bellrose 1976:143-144). It would be disadvantageous for a goose that has lost a mate during fall or winter to wait until arrival on the nesting area the following spring before forming a new pair bond (Hanson 1953, Barry 1962, Martin 1964) since successful reproduction in geese that nest in the north often depends on nesting as soon as nest sites are available (Cooch 1961, Barry 1962, MacInnes 1962, Raveling 1978b). A delay in egg-laying due to time spent pairing and/or developing the proper physiological condition to lay following pairing would probably lead to unsuccessful nesting (Wege and Raveling 1983).

Possibly Canada geese do pair, especially after the death of a mate, during winter, and avoid "mis-pairings" with sympatrically occurring subspecies through recognition of their subspecies "identity" (Roy 1980:5). Johnson et al. (1979) demonstrated significant morphometric differences between subspecies of Canada geese that migrate to wintering areas along the Pacific Flyway. Relative size and plumage differences are important cues for sex and species recognition in many birds (Cooke 1980), and may also be operating as mechanisms for subspecies recognition in geese. Subspecies identity may be further augmented by the ability of geese to discriminante subspecies-specific behaviors. Behavioral "flags" (among other factors) may serve as cues that help geese maintain traditional group cohesion and inhibit pair formation (and subsequent breeding) between individuals of different subspecies ("ethological isolation" at the subspecies level, Brown 1975:404-405).

Dusky and Taverner's Canada geese frequently mixed (11-90% dusky) in feeding flocks both during and after hunting season (73% mixed, N = 1242). Skeins of mixed subspecies were observed much less frequently (20% mixed, N = 1376). The differences in emphasis and/or range in behavioral repertoires between dusky and Taverner's geese probably helps promote segregation in commuting flight from roost to feeding fields and from field to field. What appears to human observers as free mixing and behavioral homogeneity in feeding flocks composed of different subpecies of geese may be due to proximate factors. Different subspecies of Canada geese probably feed in mixed flocks as a result of proximate advantages (e.g. food quality, group size, etc.) rather than because of an inability to discriminate subspecies identity.

Management Implications

Simpson and Jarvis (1979) and Timm et al. (1979) emphasized the need for flexible management strategies that provide hunting of the increasing numbers of Taverner's Canada geese wintering in Oregon's Willamette Valley as well as the static or declining population of duskys. Management relying only on the geographic separation of these subspecies may provide limited success towards this goal. Simpson and Jarvis (1979) found that duskys were more often associated with federal waterfowl refuges than Taverner's. My data support Simpson and Jarvis' (1979) findings that duskys wintering on Sauvie Island frequented fields on the state management area during hunting season, while Taverner's generally used fields on privately-owned land.

Protecting refuges and state management areas from hunter disturbance may help to reduce hunting mortality for duskys, however, in my study, feeding flocks of geese contained both subspecies more often than not and protection of any area from hunting would probably create a sanctuary for both subspecies ("refuging").

It is my opinion that the difference in hunting vulnerability between dusky and Taverner's geese is a manifestation of hunting techniques adapted to hunting a traditional, predictable subspecies (e.g. duskys) and behavior differences between subspecies. Duskys have been established and hunted in western Oregon since at least the 1950's, while Taverner's first occurred in substantial numbers in the early 1970's. The establishment of hunting regulations that lead to the re-education (via incentives) of waterfowl hunters to the behavioral differences between these subspecies probably provides the best opportunity for selective management. A system that encourages the hunting of Taverner's (e.g. different bag limits by subspecies, or a point system that favors hunters that shoot Taverner's) combined with some manipulation of feeding fields (e.g. creating "small" fields, using dusky-type decoys in protected areas, etc.) on sanctuaries traditionally used by duskys is recommended.

Further Research

My study may have been specific to the geese that winter on Sauvie Island, Oregon, the study season, and/or particular inter-relationships among habitat variables at this location. Further research is recommended in different locations where several subspecies of Canada geese winter sympatrically and for additional variables that seem to influence behavior and habitat use. Additional variables deserving investigation include family and dominance relationships, flight activity, nocturnal activity, physiological condition, food availability, food preference, and competitive interactions between subspecies.

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APPENDIX

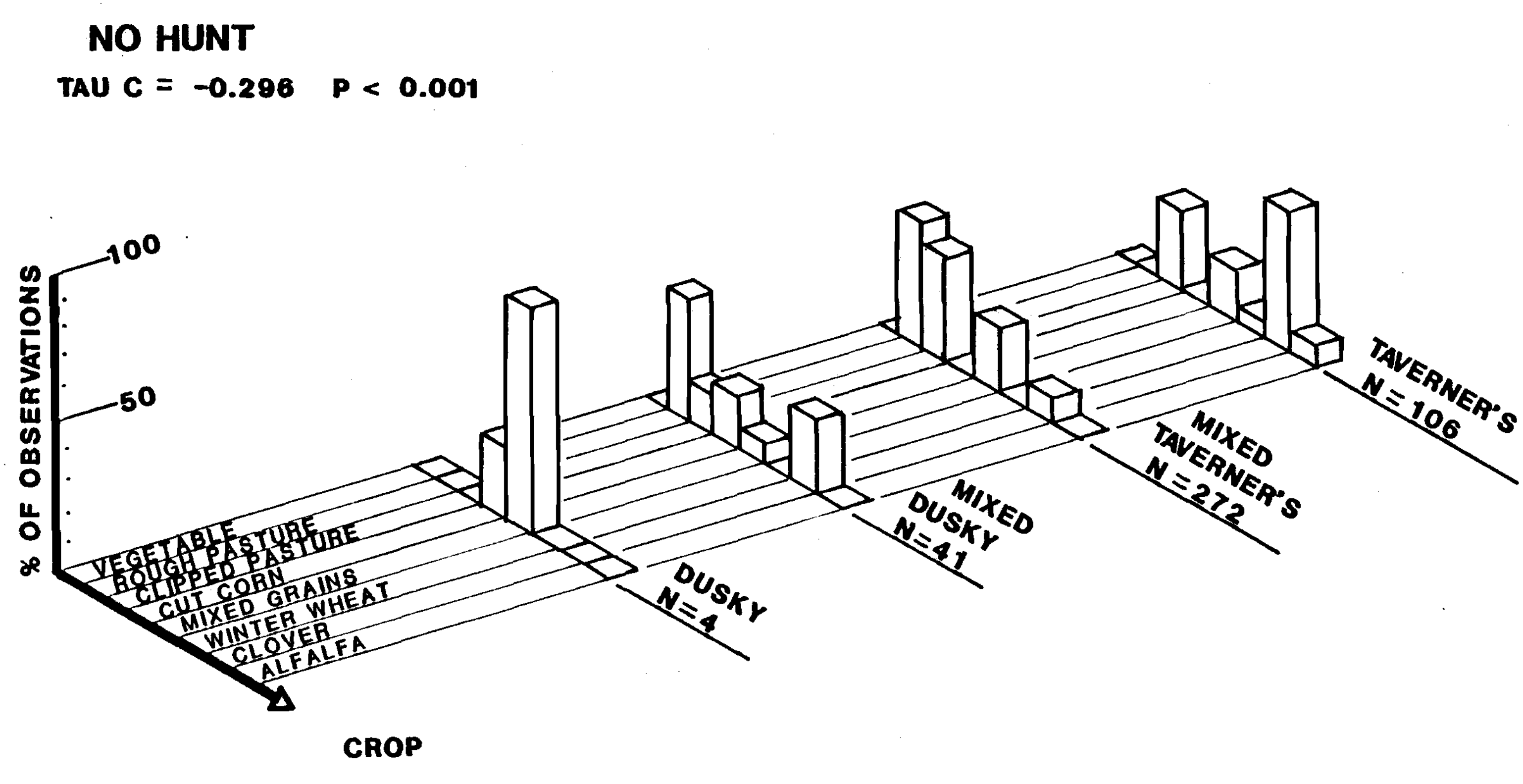

Figure 1A. Frequency distribution of feeding flocks of Canada geese according to subspecies composition after waterfowl hunting season (NOHUNT) on Sauvie Island, Oregon, 1981-82 for 8 categories of crop. Dusky = flocks of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

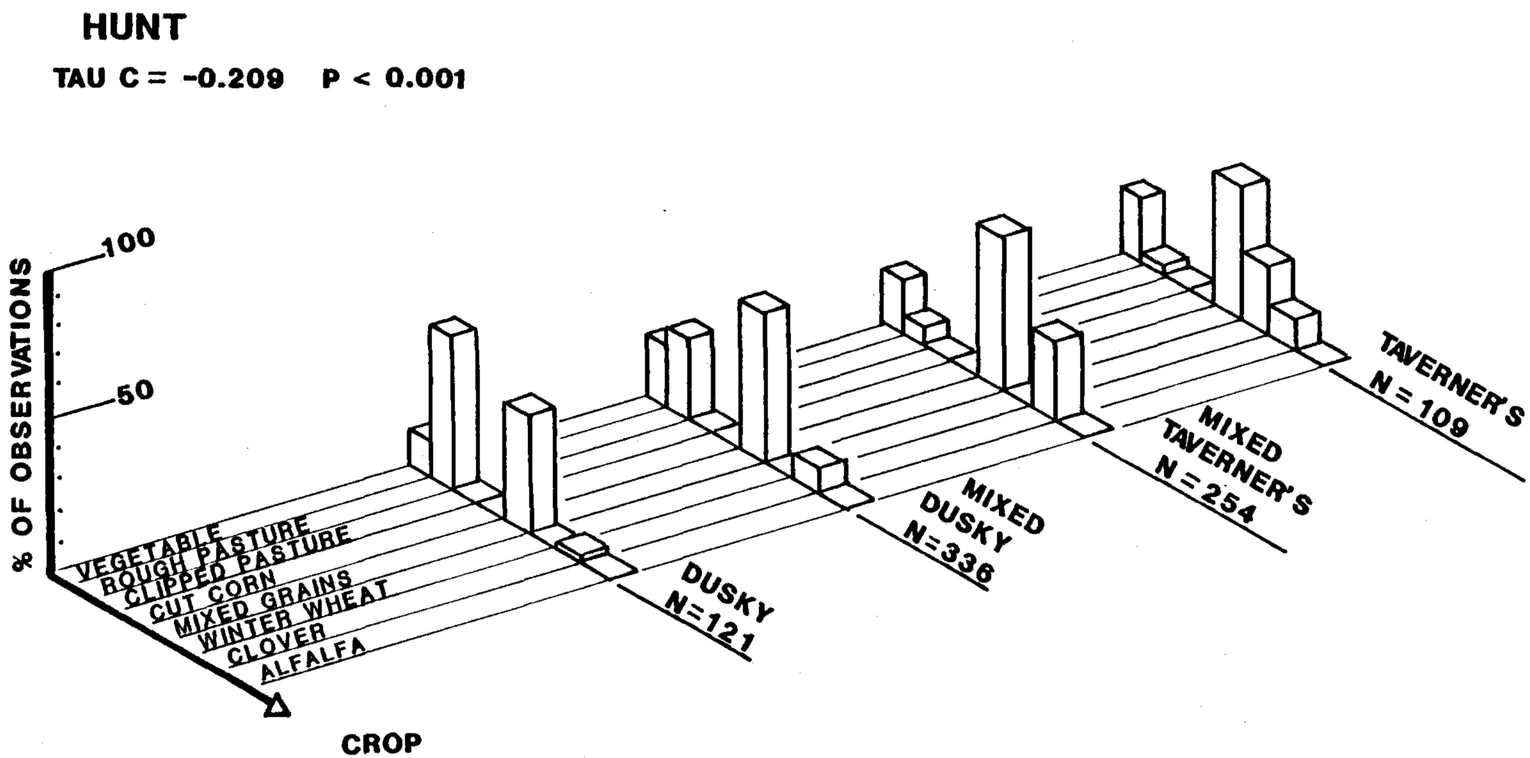

Figure 1B. Frequency distribution of feeding flocks of Canada geese according to subspecies composition during waterfowl hunting season (HUNT) on Sauvie Island, Oregon, 1981-82 for 8 categories of crop. Dusky = flocks of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

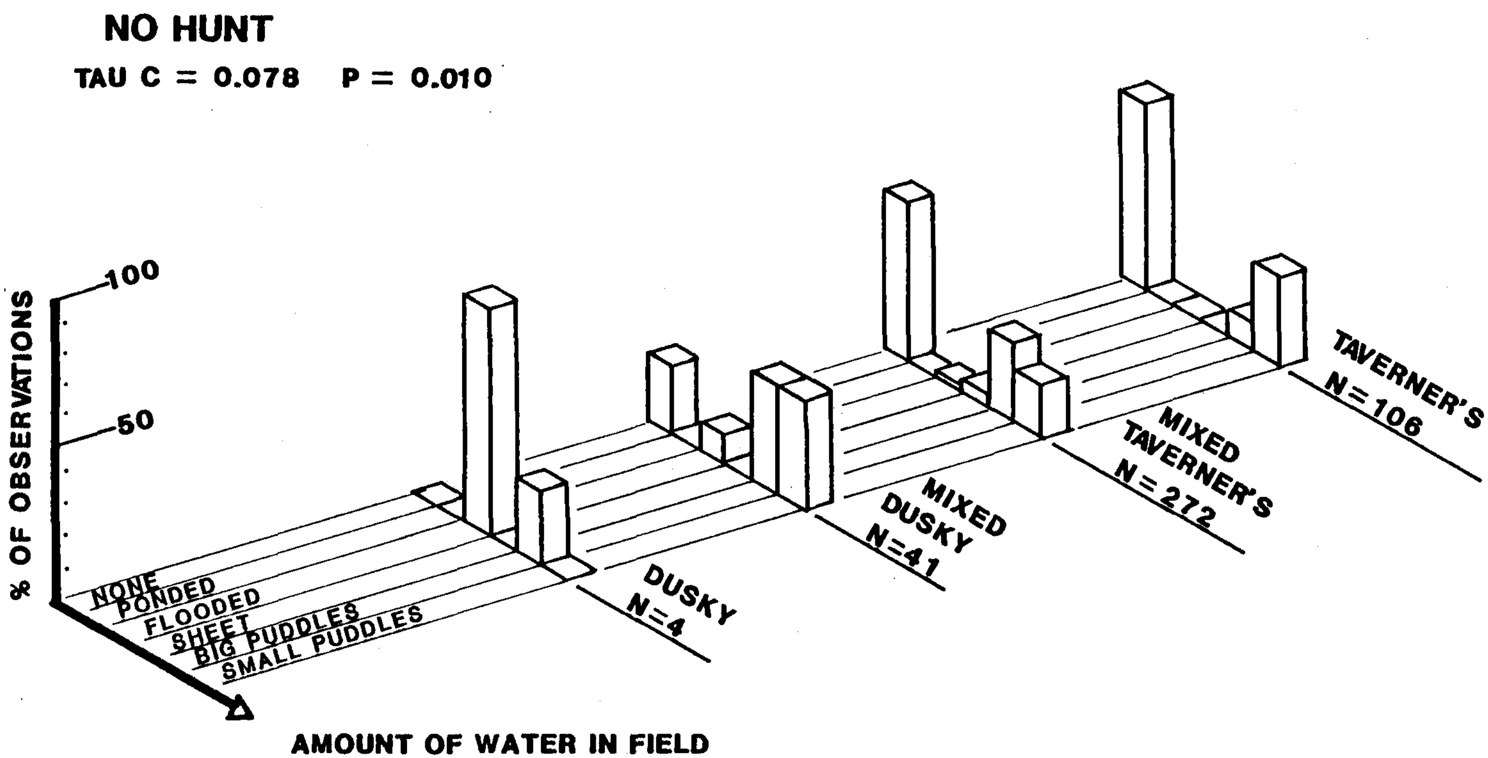

Figure 2A. Frequency distribution of feeding flocks of Canada geese according to subspecies composition after waterfowl hunting season (NOHUNT) on Sauvie Island, Oregon, 1981-82 for 6 categories of the amount of water visible in a field. Dusky = flocks of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

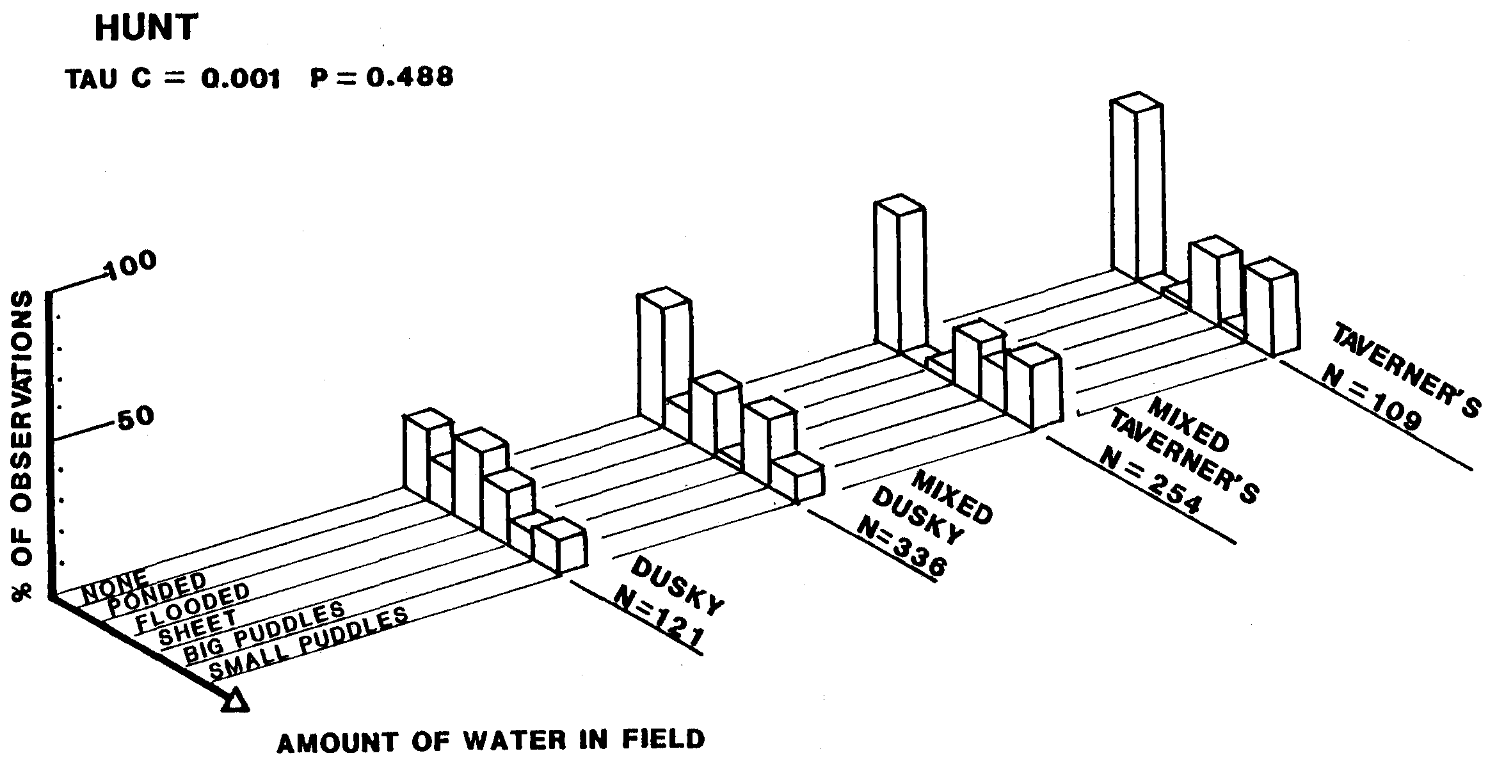

Figure 2B. Frequency distribution of feeding flocks of Canada geese according to subspecies composition during waterfowl hunting season (HUNT) on Sauvie Island, Oregon, 1981-82 for 6 categories of the amount of water visible in a field. Dusky = flocks of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

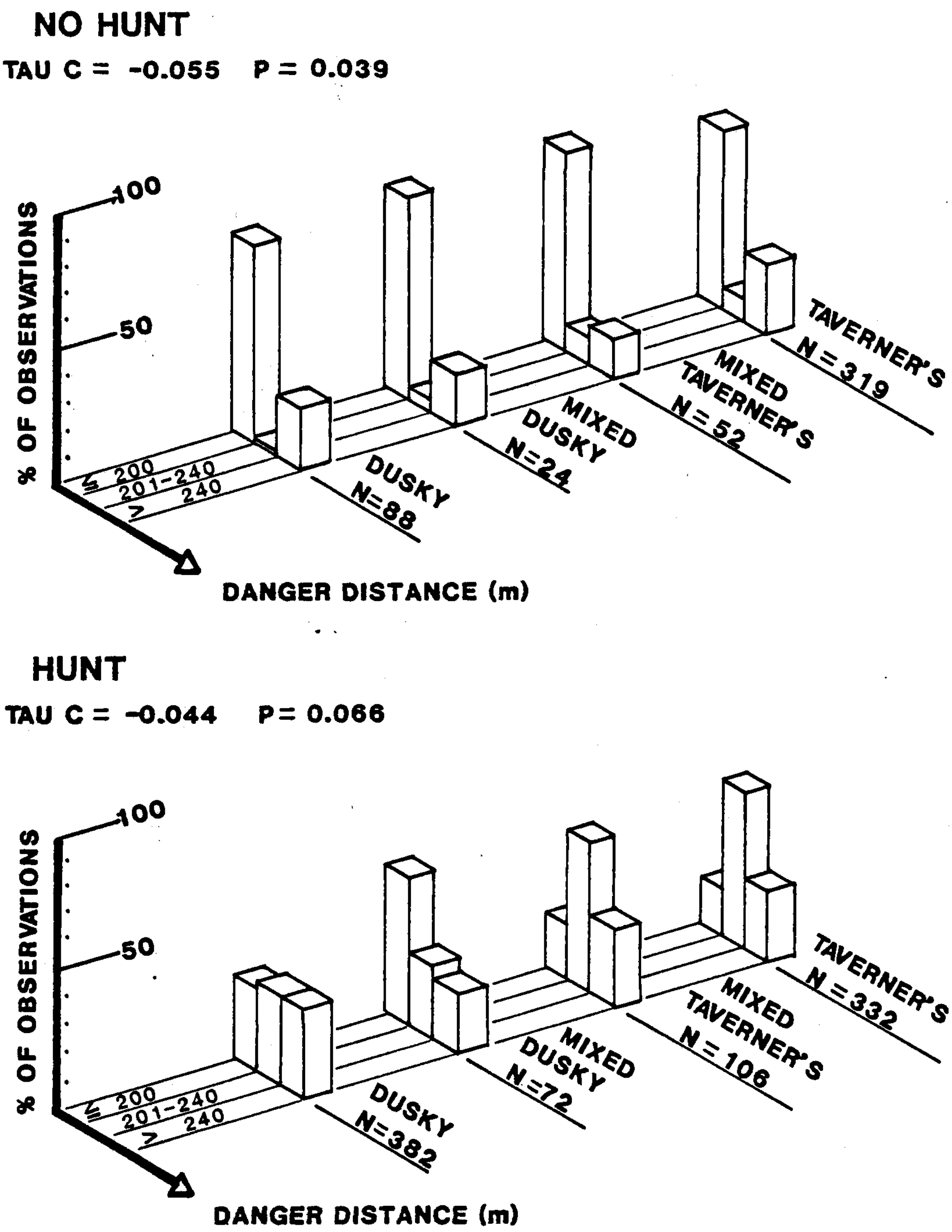

Figure 3. Frequency distribution of skeins of Canada geese according to subspecies composition during (HUNT) and after (NOHUNT) waterfowl hunting season on Sauvie Island, Oregon, 1981-82 for 3 categories of the distance from danger. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

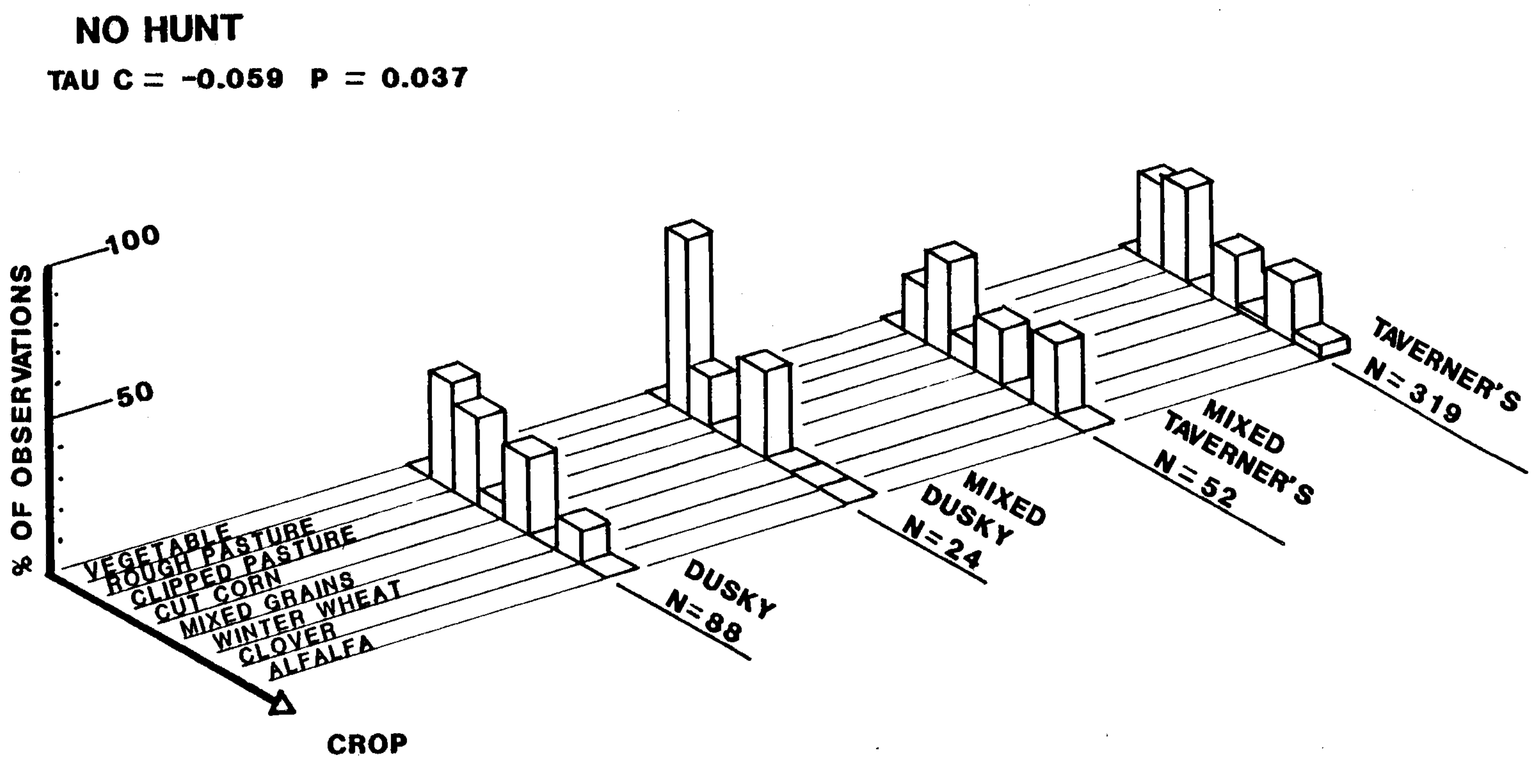

Figure 4A. Frequency distribution of skeins of Canada geese according to subspecies composition after waterfowl hunting season (NOHUNT) on Sauvie Island, Oregon, 1981-82 for 8 categories of crop. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

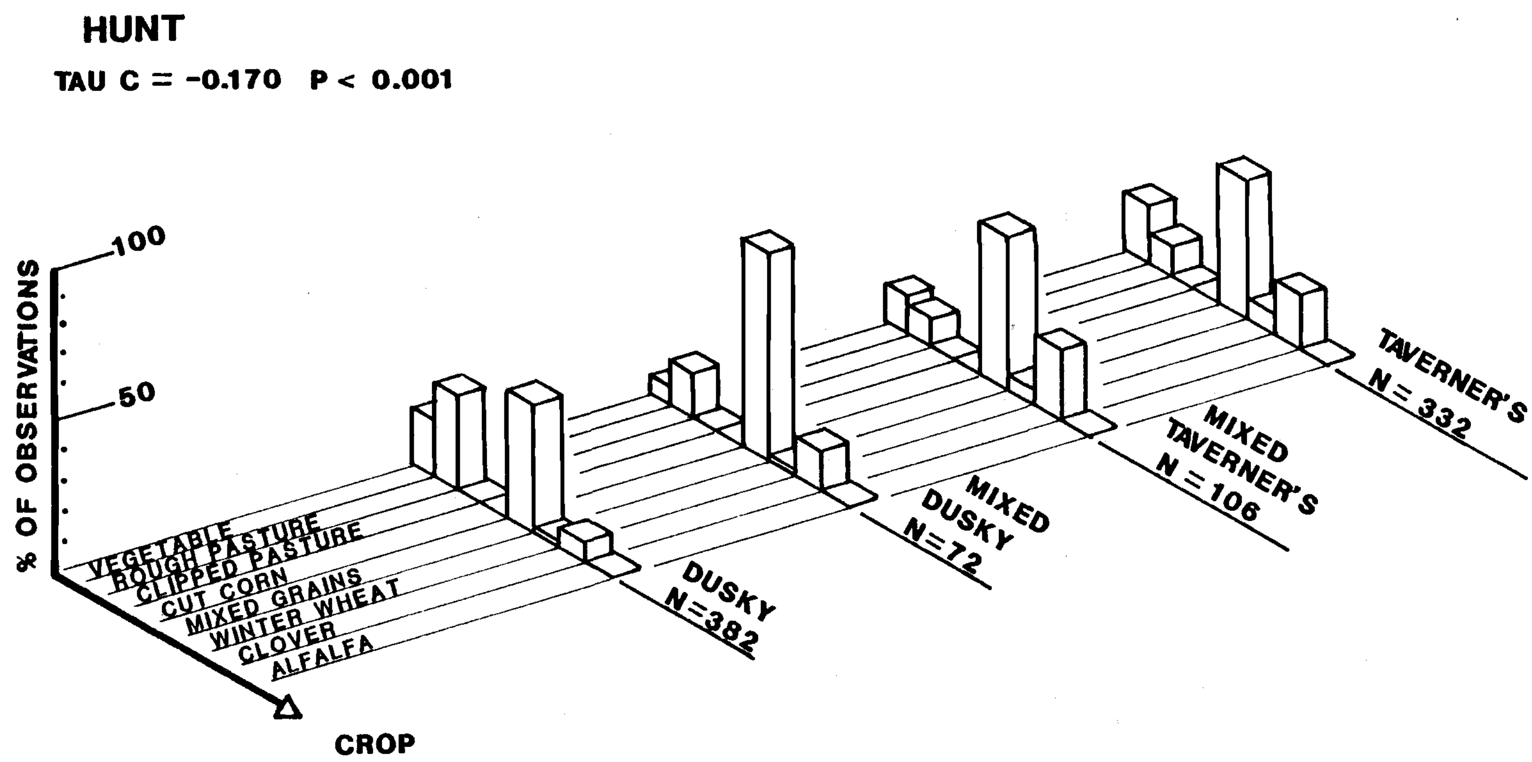

Figure 4B. Frequency distribution of skeins of Canada geese according to subspecies composition during waterfowl hunting season (HUNT) on Sauvie Island, Oregon, 1981-82 for 8 categories of crop. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

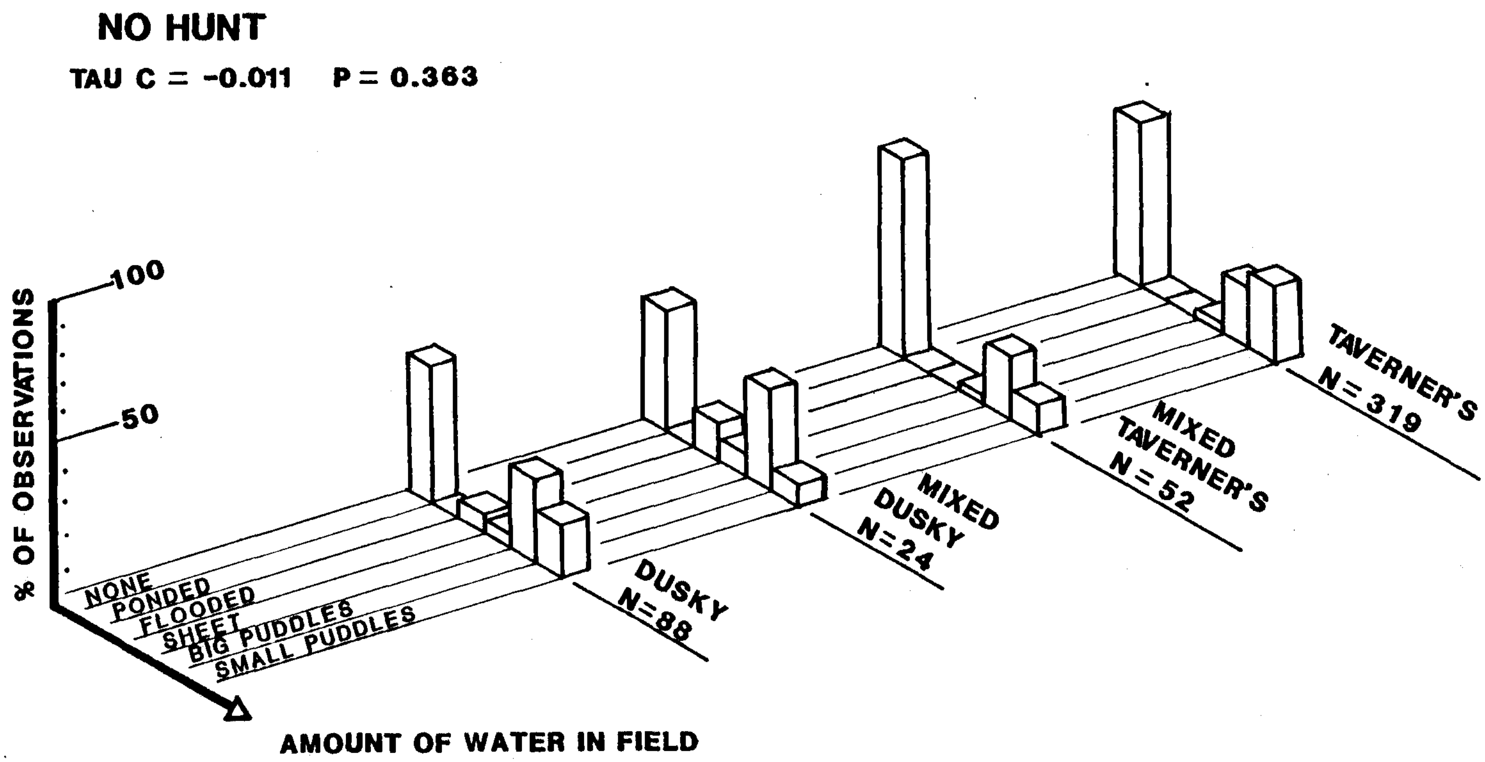

Figure 5A. Frequency distribution of skeins of Canada geese according to subspecies composition after waterfowl hunting season (NOHUNT) on Sauvie Island, Oregon, 1981-82 for 6 categories of the amount of water visible in a field. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.

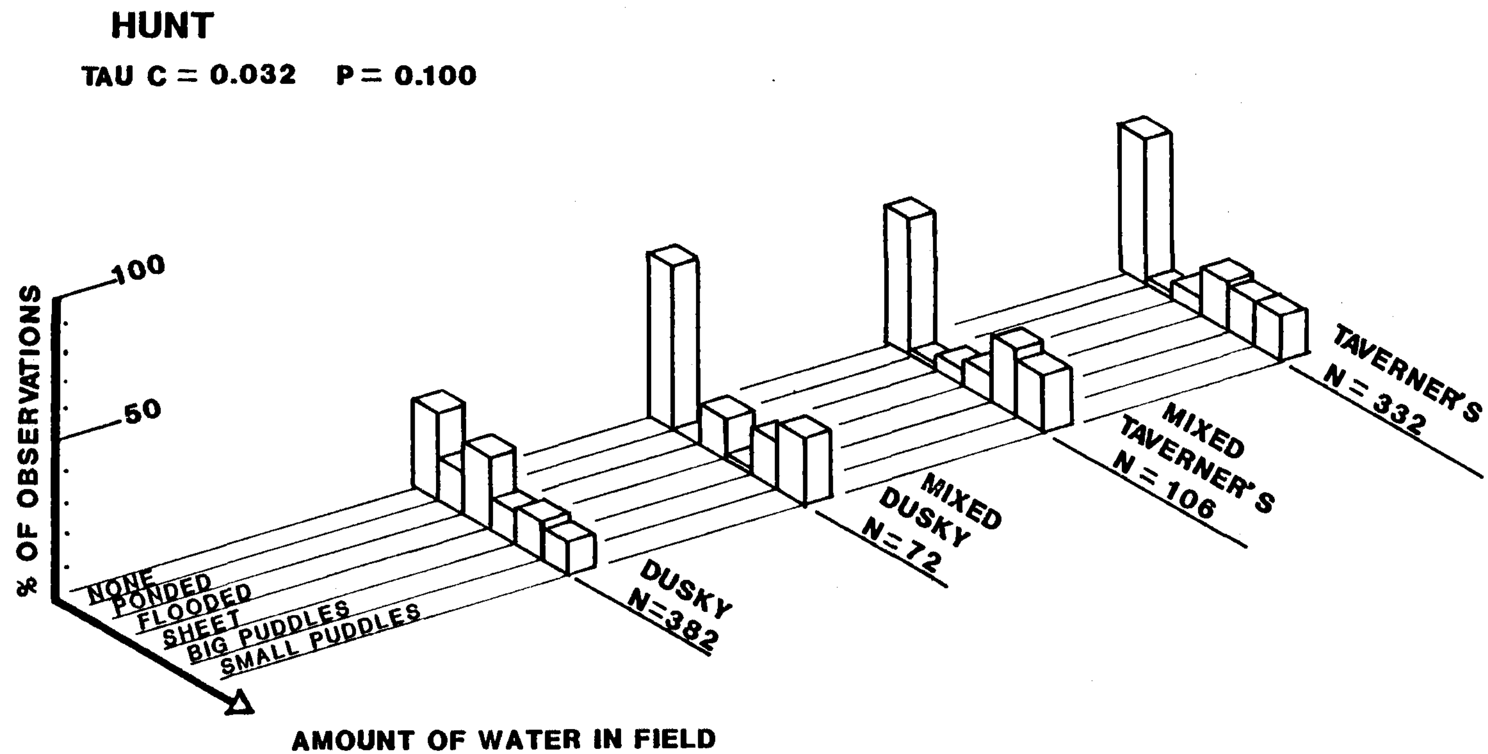

Figure 5B. Frequency distribution of skeins of Canada geese according to subspecies composition during waterfowl hunting season (HUNT) on Sauvie Island, Oregon, 1981-82 for 6 categories of the amount of water visible in a field. Dusky = skeins of 91-100% dusky, mixed dusky = 51-90% dusky, mixed Taverner's = 11-50% dusky, and Taverner's = 0-10% dusky.