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OBSERVER EFFECTS IN SHIPBOARD SIGHTING SURVEYS OF DOLPHIN ABUNDANCE

by

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ADMINISTRATIVE REPORT LJ-84-30

Observer Effects in Shipboard Sighting Surveys of Dolphin Abundance

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ABSTRACT

We investigated observer searching patterns and the effects of observer experience and environmental factors upon observer's abilities to detect dolphin schools and estimate dolphin school size and composition during two research vessel sighting surveys conducted in the eastern tropical Pacific in 1982 and 1983. During the 1983 cruise, observers with exclusively research vessel experience displayed a higher mean dolphin detection rate than observers with exclusively tuna vessel experience. During the 1982 cruise, there was no difference between mean detection rates of the two types of observer. The two observer types did not differ in their estimates of average school size or species proportions. Watch lengths from 1 to 3 hours did not significantly affect detection rates. Observers positioned on both sides of the ship searched through mounted binoculars from abeam to across the bow; the observers concentrated their effort around the trackline. Sun glare off the bow resulted in a decrease, though not complete curtailment, of searching on the trackline.

INTRODUCTION

Reliable estimates of dolphin population size are required for determining the effects of incidental dolphin mortality associated with the eastern tropical Pacific (ETP) yellowfin tuna purse seine fishery. A recent assessment of ETP dolphin population sizes by Holt and Powers (1982) combined dolphin census data from aerial surveys, research vessel surveys, and observations made by U.S. Government observers aboard commercial tuna vessels. Those authors discussed several uncertainties associated with population size estimates based on data from these sources. Holt (ms.)[1] subsequently addressed problems associated with aerial surveys.

This paper presents the results of experiments designed to investigate observer performance and environmental effects during the three basic phases of a research vessel dolphin population survey: searching, detection, and school description. The study addressed the following questions:

1. What searching patterns do observers exhibit when using mounted binoculars?

2. Does watch length affect the rate at which observers detect dolphins?

3. Does sea state affect observers' dolphin detection rates or estimates of school size and species composition?

4. Do observers with experience detecting dolphins from tuna vessels differ from observers with research vessel experience in their

   (a) searching patterns,

   (b) dolphin school detection rates,

   (c) school size estimates,

   (d) species identifications, or

   (e) species proportions estimates?

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[1]Holt, R.S. ms. Testing the validity of line transect theory to estimate density of dolphin schools.

DATA COLLECTION

Data were collected during two separate dolphin sighting survey cruises using the National Oceanic and Atmospheric Administration ship *David Starr Jordan*. The ship traversed systematically-placed tracklines in the ETP (Figure 1). The first cruise, from May 15 to August 3, 1982, surveyed a region designated the calibration area by Holt and Powers (1982) and along 10° N latitude. The second cruise, from January 12 to April 9, 1983, covered primarily the calibration area and along 10° S latitude.

On board each cruise were six observers who were divided into two teams of three each. One team consisted of observers who had experience collecting data on dolphins in the ETP from aboard research vessels (research-vessel experienced [RVE] observers). The other team consisted of observers with experience aboard commercial tuna purse seine vessels (tuna-vessel experienced [TVE] observers) but no research vessel experience. Observers were selected based on their experience and availability, but not on their previous performance. Except for one RVE observer who was present on both cruises, different observers were on board each of the two cruises.

A watch was defined to be a period of continuous marine mammal observation effort conducted by a team. Activities performed during a watch included searching through binoculars, recording data, tracking and approaching schools, and making school size and species composition estimates. The teams alternated watches during daylight hours and also alternated conducting the first watch of the day. When a substitute observer was required during a watch, the watch was credited to the team represented by the two permanent members. If more than one substitute was required, the watch was not used in subsequent analyses. Watches were terminated for team rotation, for relief for meals, or if interrupted for more than five minutes because of poor visibility due to fog or rain. Watches which were less than 30 minutes long were designated short watches.

Watch lengths of either one, two, or three hours were systematically rotated every two days throughout the 1982 cruise, and during the first third of the 1983 cruise. Watches rarely lasted precisely a whole number of hours; a watch was assigned to the 1- , 2- , or 3-hour category by rounding the watch length to the nearest whole hour.

Three duty stations were occupied by team members during each watch: left (port) binocular, right (starboard) binocular, and recorder. Team members rotated positions approximately every 15 minutes throughout the watch so that each team member spent approximately the same amount of time occupying each duty station.

Observers stationed at the binoculars searched for marine mammal sighting cues (dolphins, splashes, or birds) through 25x binoculars. Searching ranged from across the trackline (an 0.28 km strip on either side of the ship) to abeam, and outward to the horizon, or as far as was possible under the prevailing sighting conditions. Searching pattern was monitored during the last third of the 1982 cruise and the entire 1983 cruise by an onboard computer which recorded train angle of the binoculars within 5^{o} sectors at five second intervals while searching effort was in progress.

The recorder logged time, position occupied by each team member, sea state, environmental conditions, and speed and heading of the ship. Data were recorded when the observers rotated position or a change occurred in sea state, environmental conditions, or speed or heading of the ship. Sea state was measured by the Beaufort scale (Bowditch, 1966) and grouped into two categories for subsequent analysis: calm (absence of white caps, Beaufort numbers 0-2) and rough (presence of white caps, Beaufort numbers 3-5). We encountered no sea states with Beaufort value greater than 5. The recorder searched through 7x binoculars when not recording data.

When a dolphin sighting cue was detected, the sighting angle (relative to the trackline) and radial distance to the school were recorded. The sighting was credited to the team on watch, rather than the individual detecting the cue, because there was no basis for assuming that sightings by individual observers were independent of the influence of other members of the team. The three observers on watch plus any available observers from the team not on watch independently estimated school size, identified species present, and estimated species proportions. This allowed us to compare simultaneous estimates by the two teams. The ship usually altered course to approach a sighted school. Observer estimates of school size and species composition were based upon observations made at the shortest possible distance to the school, rather than at the initial time of sighting. The chief scientist, who was not a member of either team, transferred all school size and species composition estimates to sighting records at the end of each day.

The 1982 observers were instructed not to discuss their species identifications or school size and proportions estimates with one another. The 1983 observers were instructed not to discuss school size or species proportions estimates, but were allowed to discuss species identifications after independent identifications had been recorded.

Upon completion of both cruises, searching effort and sighting data were analyzed by standard statistical techniques, with the aid of BMDP statistical programs (Dixon, 1981). We analyzed sizes and compositions only for schools whose mean size estimate was greater than or equal to 15 (termed large schools) and which contained dolphin species targeted for capture by the ETP tuna fishery. Target species were the spotted, spinner, common, striped, and Fraser's dolphins. We restricted our analysis to large target schools in order to parallel the abundance assessment of Holt and Powers (1982) whose study also was limited to large target schools.

Data are reported as means plus or minus one standard deviation. Statistical tests were considered significant at the 0.05 (5%) level of probability.

SEARCHING PATTERN

Observer searching patterns are perhaps the most important aspect of the sighting survey process. Individual and combined searching habits have not been fully described. We were primarily interested in studying the effects of sun glare and observer experience on searching patterns.

We calculated the percent of total searching effort in 5° segments of arc for all observers at both the port and starboard binoculars (Figures 2 and 3). Most observers searched primarily forward from the trackline to abeam (90° to the trackline) on the same side as the binocular was mounted and from the trackline to about 45° on the opposite side. Three observers (numbers 8, 10, and 11 from the 1983 cruise) displayed searching patterns which ranged to less than 45° on the opposite side (Figure 3).

Doi et al (1982) used a video camera to record observers' searching behavior through hand-held binoculars. They concluded that observers searched most frequently towards the trackline, but their conclusion was based upon the frequency with which the binoculars crossed 10° radial lines, rather than the proportion of effort. They also assumed that angular scanning velocity was constant, but they only measured angular velocity between turning points (where observers reversed scanning direction). Our finding that percent effort was greatest around the trackline confirms their conclusion. In fact, the searching patterns displayed in Figures 2 and 3 are similar to the patterns displayed in their figures.

Differences in searching patterns due to sun location and team were analyzed by grouping searching effort into eight sectors of arc (Figure 4). Counts (numbers of 5-second intervals) were analyzed for each binocular by team, sun location, and sector. Sun location was assigned to one of five classifications based on its horizontal and vertical relationship to the ship (Table 1).

Because of large sample sizes, tests of all interaction effects were highly significant for both binoculars during both cruises (Tables 2 through 5). Differences in searching patterns due to sun category and team were therefore interpreted in terms of practical significance, or relative magnitude, rather than statistical significance.

Differences between searching effort with the sun overhead or to the rear (aft category) and searching effort with the sun obscured by clouds (cloudy category) were so small that these were combined into a single category for comparison to searching effort in the presence of sun glare. Searching effort in the absence of sun glare was nearly symmetrical about the trackline (Figure 5), except that effort in the 0° to 15° sector on the port side was slightly less than on the starboard side due to a small obstruction which interfered with the starboard observer's searching the port area. The presence of sun or sun glare in the field of view along the trackline was accompanied by a decrease in searching effort in that direction. Frequency of searching in the 0° to 15° sectors on both sides of the trackline was relatively less during both cruises when the sun was in the bow category. Frequency of searching from 0° to 45° on the port side was substantially less than on the starboard side when the sun was off the port side. When the sun was off the starboard side, however, searching frequency on the starboard side was not less than on the port side.

Holt (ms.)[2] classified effort that occurred when the sun was within the bow category (Table 1) as poor sun conditions and all other effort as good sun conditions. He concluded that sun glare had little effect upon the density estimates during the 1982 and 1983 cruises. Poor sun conditions occurred only during 5% of the 1982 cruise effort and 8% of the 1983 cruise effort. Rates of detecting dolphin schools on the trackline were higher during poor sun conditions than during good sun conditions in 1982; no trackline schools were detected during poor sun conditions in 1983. Detection rates of sightings made within either 2.1 or 7.4 km of the ship were not affected by sun condition.

During the 1982 cruise, the two teams' searching patterns were similar (Figure 6). During 1983, however, the TVE observers' frequency of searching effort within 15^{o} of the trackline was greater than that of the RVE observers. This increased effort on the trackline by the TVE team during 1983 compensated for a decrease in effort to the side opposite each binocular; both teams searched equally the areas on the same side of the trackline as the binoculars. This difference in effort on the trackline apparently did not affect the perpendicular distances to sighted schools because an analysis of the relationship between team and perpendicular distance was not significant (Tables 6 and 7).

DOLPHIN DETECTION RATES

Even if observers searched adequately, some dolphin schools may not have been detected. The rate of detecting schools, apart from the effect of their distribution, might have been affected by observer fatigue, an observer's experience, or sea state. We examined the effects of each of these factors on detection rates.

To study the effects of observer fatigue, we analyzed changes in detection rates with varying watch length using analysis of variance (ANOVA). Sighting rate for each watch was defined as the number of sightings divided by the amount (in time) of search effort. A three-way ANOVA (with watch length, team, and sea state as factors) was used for data from the 1982 cruise. The effect of watch length, and interaction between watch length and team, during 1983 were tested using a two-way ANOVA applied only to 1983 data from the first third of the cruise, since watch length was not varied for the rest of the cruise. Effects of team and sea state, and the interaction between the two, during the 1983 cruise were tested using a two-way ANOVA applied to the entire 1983 data set.

Classical ANOVA was used for analyzing sighting rates, although sighting rates were not normally distributed and unequal numbers of watches occurred in the various watch length categories. A normalizing transformation of the data could not be found. A nonparametric test could

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[2]Holt, R.S. ms. Estimation of density of dolphin schools in the eastern tropical Pacific using line transect methods.

have been performed, but several interdependent tests would have been required to test effects of all three factors, which would have resulted in an unknown overall significance level. Such tests also would not have tested interaction effects.

Glass et al (1972) and Scheffe (1959) discussed the implications of deviations from the basic ANOVA assumptions: normality, equality of cell sizes, and equality of variances. There appears to be no solution to the problem of performing two- or three-way ANOVA with interactions when the assumptions are all simultaneously violated, and no suitable alternative to classical ANOVA in the two- or three-way case is available. Therefore, we chose to proceed with classical ANOVA. Marginally significant results (those with significance levels near 0.05) could not be interpreted, but results which were highly significant or highly non-significant were considered valid.

A total of 186 dolphin sightings was made during 1982: 116 by the RVE team and 70 by the TVE team. During 1983, 201 dolphin schools were sighted: 123 by the RVE team and 78 by the TVE team. Analyses of variance of dolphin detection rates (Tables 8 through 10) revealed no significant effect of watch category ($p=0.14$, 1982 cruise; $p=0.51$, 1983 cruise), and no significant interaction effect between watch category and team ($p=0.84$, 1982 cruise; $p=0.93$, 1983 cruise).

We discovered that sighting rates during short watches were consistently higher than those during longer watches. This suggested that observers may have been more alert in the first few minutes of a watch. We tested this by comparing sighting rates within the first 15 or 30 minutes of a watch to rates during the remainder of the watch using a paired sample t test (Table 11). Data for the 1- , 2- , and 3-hour watch categories were combined; data for short watches were omitted. There was no significant difference in dolphin detection rates when comparing either the first 15 or 30 minutes of a watch to the remainder of the watch during either cruise.

We concluded that, in terms of sighting rates, no watch length between 1 and 3 hours was superior. Discussions with the observers revealed that they preferred the 2-hour watches because of too frequent rotation with the 1-hour watches and the excessive length of the 3-hour watches. For this reason, 2-hour watches were used exclusively after the first third of the 1983 cruise.

Dolphin detection rates by the two teams were not significantly different during the 1982 cruise ($p=0.13$, Table 8), but were significantly different during the 1983 cruise ($p<0.001$, Table 10). During 1983, there was also a significant interaction between team and sea state ($p<0.001$). The RVE observers made approximately twice as many sightings as TVE observers during calm seas and nearly two and one-half times as many sightings during rough seas.

Holt (m.s.)2 calculated dolphin school density estimates for the 1982 and 1983 RVE and TVE team's data. Although the two 1982 team's searching patterns near the trackline were similar, the TVE team's density estimate was less than one half the RVE team's estimate. This was because the TVE team's rate of detecting dolphins near the trackline was substantially less than the RVE team's rate despite similar overall detection rates by the two teams. Although the 1983 TVE team spent more effort than the RVE team searching the bow sector, the two team's dolphin detection rates were similar out to 2.13 km perpendicular distance, but the TVE team's rate was less outside this band. Despite the increased effort of the TVE team near the trackline, density estimates for the 1983 teams were similar.

Differences in searching behavior and sighting rates may have been due to the differences in the team's searching experience. The TVE observers do not use 25x binoculars for searching when on board commercial tuna vessels. They must rely on members of the tuna vessel crew to make sightings, or else use 7x binoculars. The RVE observers, however, are experienced at searching through 25x binoculars.

There was no significant effect of sea state on dolphin sighting rate during the 1982 cruise (p=0.49; Table 8), but the effect was highly significant during the 1983 cruise (p<0.001; Table 10). The effect of sea state may have been due to difficulty in detecting splashes made by the dolphins during rough seas. Rough seas occur during periods of strong wind, but the effect of the wind on the presence of birds, another sighting cue, is unknown.

Differences in sighting rates between calm and rough sea state categories might have been due to a difficulty in detecting sighting cues at large perpendicular distances from the trackline. However, there was no significant association between perpendicular distance of sightings and sea state during either cruise (Tables 6 and 7).

SCHOOL SIZE AND COMPOSITION

Once a dolphin school was sighted, observers made estimates of its size and species composition. For estimating species composition, the observers were required to identify species present within the school, as well as proportions of each species present in schools of mixed composition. We tested for possible differences in the observers' estimates of school size and composition due to differences in their experience or to changes in sea state.

School Size

To test school size, we applied ANOVA with two factors (observer and sea state) to log-transformed school size. There was no significant observer effect during either year (p=0.62, 1982; p=0.36, 1983), and no significant interaction between team and sea state (p=0.89, 1982; p=0.83, 1983) (Tables 12 and 13).

One problem with using ANOVA to test differences in school size estimates among observers was that school sizes varied over two orders of magnitude. This large variability was therefore likely to mask any differences among observer mean school size estimates. Differences between team average school size estimates were therefore tested in an alternate way which controlled the variability in school size. For each sighting where both teams estimated school size, the mean school size was computed for each team. The difference between the two team averages for that sighting was calculated, and then divided by the mean of the combined estimates of all observers. The resulting standardized differences were therefore not confounded with school size.

The standardized differences were plotted separately for each cruise and sea state as a function of sighting sequence through time (Figure 7). Gaps in the figure are due to sightings for which school size estimates were not simultaneously made by both teams. The mean standardized differences were tested for a significant difference from zero by one-sample t-tests (Table 14); only the test for calm sea state during 1983 was significant (p=0.038) with the TVE observers' school size estimates being larger than the RVE observers' estimates. Since this was the only significant result obtained from both methods (ANOVA and the standardized difference t-test), we concluded that the RVE and TVE observers did not make significantly different school size estimates.

Independence of simultaneous school size determinations might have been difficult to achieve because of proximity of the observers making estimates following a sighting. However, standardized differences between average school size estimates by the two teams (Figure 7) did not approach zero, suggesting that school size estimates by the two teams did not converge during either cruise. We therefore assumed that observers did not discuss or reveal their individual school size determinations throughout the duration of the cruise.

There was no significant effect of sea state on school size estimates during either cruise (p=0.23, 1982; p=0.14, 1983). The presence of white caps might have had an effect on school size estimates made at large distances to the school, but most schools were seen at close range since the ship usually approached sighted schools.

We hoped that the RVE and TVE observers used in this study would be representative of the larger groups of research and tuna vessel observers. However, a random sample of observers was not obtainable, and no inexperienced observers who had been trained but not assigned a cruise were available. All selected observers except one had participated in at least two previous cruises (Table 15).

The TVE observers' abilities to estimate dolphin school size were compared with those of all other observers aboard tuna vessels. Log-transformed school size estimates made by our selected TVE observers while aboard tuna vessels between 1978 and 1982 were compared with log-transformed estimates made by all other tuna vessel observers during those same years. Mean school size estimates and standard deviations were computed for each of the two TVE teams and for all other tuna vessel observers (Table 16). Since the number of estimates by the group of all other tuna vessel observers was large, the mean for that group was regarded as an estimate of the true population mean, and a one-sample t-test was performed for each TVE team.

Mean log school size estimates by the TVE team members were significantly lower than those for all other tuna vessel observers ($p<0.001$). Our selected TVE observers therefore were not representative of all tuna vessel observers, which included inexperienced (first trip) observers. An observer's school size estimate may decline with experience aboard tuna vessels but additional study is required.

Comparisons of the RVE observers' abilities to estimate school size with those of all other research vessel observers were not possible. Individual estimates made by our selected RVE observers on previous research cruises could not be determined because prior to the 1982 cruise the averages of all observers' estimates, rather than individual estimates, were recorded. Since, as with the TVE observers, the RVE teams were not selected randomly and did not include any inexperienced observers, they also may not be representative of their group as a whole.

Species Identifications

We tested differences in species identifications in two stages. In the first stage, we investigated the percentage of large schools for which identifications were made. Three-way contingency tables were used to test for interactions between frequency of identifications and sea state or frequency of identifications and team. In the second stage, we tested frequency of individual species identifications by analyzing a three-way table with team, sea state, and species as categories. We included separate classes for each target species except Fraser's dolphin, all non-target species, and mixed spotted and spinner schools. Fraser's dolphins were omitted because only one school was sighted during the two cruises.

During 1982, RVE observers made a significantly higher frequency of species identifications than did TVE observers (98.4% versus 89.5%, $p<0.001$; Table 17). There was no significant difference between the team's frequencies of identifications during 1983 ($p=0.072$; Table 18). There was no significant association between team and individual species during either cruise (1982: $p=0.091$, Table 19; 1983: $p=0.70$, Table 20).

The difference between teams in the frequency of identifications during 1982 may be valid and representative of a difference between RVE and TVE observers in general for two reasons. First, before embarking upon the 1982 cruise, all observers were told that an objective of the cruise was to study the degree of variability present in each observer's individual estimates. They were not informed that the effects of observer experience would be investigated, because this might have biased the outcome by encouraging competition. Upon completion of the cruise, all of the objectives of the study were explained to the observers. It was impossible, then, to conduct another research cruise without the observers being aware of the study objectives. The 1983 TVE observers may have made more of an effort to identify schools to compete with the RVE observers, thereby accounting for a lack of difference between the two. Second, the 1983 observers were not prevented from comparing methods of species identification. They were only requested to make independent identifications while viewing a school. Observers of the different teams may have learned from one another, thus increasing the similarity of their identifications.

There was no significant association between sea state and frequency of species identifications during either cruise ($p=0.95$, 1982; $p=0.072$, 1983), but there was a significant effect of sea state on the identifications of individual species during the 1983 cruise ($p=0.001$). The relative frequency of identification of spotted and common dolphins increased in poor sea state while frequencies of the mixed and other cateogries declined. No such difference due to sea state was found during 1982.

Species identifications were based on observations of behavior and morphology which should not have been substantially affected by rough seas or the presence of white caps, especially when the school was observed at close range. Perhaps the effect of sea state on identifications of individual species may be explained by a disproportionate effect of rough seas on sighting rates of the various species, since sea state had a significant impact upon sighting rate during the 1983 cruise.

Species Proportions

The estimates of the average proportions of individual species within a school were compared among observers for each target species and for all other species. The distribution of proportions for several of the species was nearly degenerate (concentrated about a single point with variance close to zero); therefore we used the nonparametric Kruskal-Wallis rank test to test for differences among observers' estimates.

The Kruskal-Wallis test results showed no evidence of any significant difference among observers in their estimates of the average species proportions within a school for any species (Tables 21 and 22). Common and striped dolphins occurred predominantly in homogeneous schools and spotted dolphins were frequently in homogeneous schools, whereas spinner dolphins were nearly always associated with spotted dolphins.

CONCLUSIONS

In this study, we investigated observer performance and environmental effects during shipboard sighting surveys of ETP dolphins in 1982 and 1983.

From our data, it was apparent that observers searched the trackline adequately. Their searching ranged from abeam to past the trackline on the opposite side. The combined searching effort of both binoculars resulted in symmetric coverage concentrated about the trackline. Searching effort along the trackline was significantly reduced, but not completely curtailed, when the sun was in front of the ship.

There was no statistically significant effect of watch length on dolphin detection rates when 1- , 2- , and 3-hour watches were compared, although short watches had slightly higher sighting rates. Sighting rates in the early part (first 15 or 30 minutes) of 1- , 2- , and 3-hour watches were not significantly greater than in the remainder of the watch. Observers preferred 2-hour watches.

The effect of rough sea state (presence of white caps) was to reduce the frequency of dolphin sightings during the 1983 cruise but not during the 1982 cruise. We could not conclude from this study whether sightings of individual species were disproportionately affected. School size estimates and the percentage of species identifications made on individual schools were unaffected by rough sea state.

We observed several differences (or lack of) between RVE and TVE observers aboard the research vessel. During the 1982 cruise, the TVE and RVE observers' searching patterns were similar. During the 1983 cruise, the TVE observers concentrated effort closer to the trackline and did not search the opposite side as much as the RVE observers. Tests of differences between the two teams in dolphin detection rates were inconclusive, with RVE observers detecting dolphins with greater frequency during 1982 but not during 1983. The two types of observer did not differ significantly in their estimates of dolphin school size. The RVE observers made species identifications on a greater percentage of dolphin schools than the TVE observers, but there was no difference between the two types of observer in their relative identifications of individual species. The RVE and TVE observers did not differ in their estimates of the porportions of various species of dolphin contained within a school.

The findings of this study provide a foundation for judging the efficacy of shipboard population surveys and comparing results from research and tuna vessels. Other uncertainties concerning shipboard sighting survey methods, including potential errors in estimating sighting angle and radial distance of schools, possible movement of animals in response to the vessel, and differences in the searching methods employed by the two types of vessel, are the subjects of further investigations. When results on the effects of these other factors are available, it will be possible to formulate a more comprehensive and reliable methodology for dolphin abundance estimation by shipboard sighting surveys.

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Table 1. Classification of sun location. Horizontal and Vertical positions were recorded to the nearest whole number. Horizontal: 12 o'clock = trackline, 3 o'clock = abeam on the starboard side, etc. Vertical: 12 o'clock = directly overhead, 1 o'clock = 60 degrees above the horizon, 2 o'clock = 30 degrees, and 3 o'clock = the horizon.

	Sun Position	
Category	Horizontal	Vertical
Bow	12	1- 3
Port	9-11	1- 3
Starboard	1- 3	1- 3
Aft	4- 8 1-12	1- 3 12
Cloudy	0	0

Table 2. Percentage of total searching effort by team, sun location, and sector for the port binocular, 1982 cruise. Sector represents the degrees of arc searched, with 0 degrees being the trackline. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

			Sector (degrees)						
			Port				Starboard		
Team	Sun Position	Total Time (Hours)	90-180	45-90	15-45	0-15	0-15	15-45	45-90
RVE	Bow	20.0	6.2	28.8	19.3	10.3	10.0	20.8	4.6
	Port	90.2	6.5	19.9	14.0	9.4	15.9	25.2	9.0
	Starboard	76.0	4.3	17.5	21.3	12.6	13.9	20.7	9.7
	Aft	230.5	3.8	19.6	22.1	12.3	12.8	22.3	7.2
	Cloudy	159.9	4.7	19.9	19.8	12.6	14.7	23.2	5.1
	Total	576.6	4.6	19.8	20.0	11.9	13.9	22.7	7.1
TVE	Bow	13.2	5.3	17.1	15.4	10.4	12.3	33.1	6.5
	Port	68.4	4.4	14.6	15.9	12.7	13.4	25.3	13.8
	Starboard	66.5	3.0	15.4	18.0	12.7	13.3	22.9	14.7
	Aft	202.3	3.9	15.4	18.2	12.5	14.7	23.1	12.2
	Cloudy	96.7	6.0	17.8	18.2	13.5	13.7	22.4	8.3
	Total	447.1	4.4	15.9	17.8	12.7	14.0	23.5	11.7

Tests of Fit by Order of Model

Order	d.f.	Chi-square	p
0-Mean	69	438616.97	<0.001
1	58	15015.66	<0.001
2	24	1778.75	<0.001
3	0	0.	1.

Tests of Partial Association

Source	d.f.	Chi-square	p
Sector	6	118114.97	<0.001
Sun	4	291839.59	<0.001
Team	1	13646.67	<0.001
Sector by Sun	24	6432.44	<0.001
Sector by Team	6	5177.37	<0.001
Sun by Team	4	1406.88	<0.001
Sector by Sun by Team	24	1778.75	<0.001

Table 3. Percentage of total searching effort by team, sun location, and sector for the starboard binocular, 1982 cruise. Sector represents the degrees of arc searched, with 0 degrees being the trackline. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

Team	Sun Position	Total Time (Hours)	Sector (degrees) Starboard 90-180	Starboard 45-90	Starboard 15-45	Starboard 0-15	Port 0-15	Port 15-45	Port 45-90
RVE	Bow	24.4	10.1	24.5	29.5	9.5	13.2	13.0	0.2
	Port	84.8	5.4	20.6	22.9	26.8	12.5	10.6	1.2
	Starboard	51.6	5.6	17.6	19.7	19.1	15.5	21.1	1.5
	Aft	248.1	7.2	21.2	22.4	16.6	15.1	15.3	2.2
	Cloudy	128.6	5.9	16.8	22.8	19.7	14.8	17.4	2.6
	Total	537.5	6.5	19.7	22.5	19.0	14.6	15.7	2.0
TVE	Bow	13.3	13.1	23.9	24.5	11.7	8.5	17.6	0.7
	Port	67.7	7.1	18.5	17.0	23.9	13.3	18.5	1.7
	Starboard	54.2	8.7	15.9	15.4	29.3	12.8	16.6	1.3
	Aft	269.4	6.4	17.6	17.7	17.9	14.1	23.6	2.7
	Cloudy	111.0	6.3	18.3	19.9	14.9	16.5	22.7	1.4
	Total	515.6	6.9	17.9	18.0	19.2	14.3	21.7	2.0

Tests of Fit by Order of Model

Order	d.f.	Chi-square	p
0-Mean	69	491513.03	<0.001
1	58	19362.63	<0.001
2	24	4208.46	<0.001
3	0	0.	1.

Tests of Partial Association

Source	d.f.	Chi-square	p
Sector	6	163908.63	<0.001
Sun	4	306629.66	<0.001
Team	1	1612.57	<0.001
Sector by Sun	24	8514.88	<0.001
Sector by Team	6	4416.02	<0.001
Sun by Team	4	1875.47	<0.001
Sector by Sun by Team	24	4208.46	<0.001

Table 4. Percentage of total searching effort by team, sun location, and sector for the port binocular, 1983 cruise. Sector represents the degrees of arc searched, with 0 degrees being the trackline. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

			Sector (degrees)						
		Total	Port				Starboard		
Team	Sun Position	Time (Hours)	90-180	45-90	15-45	0-15	0-15	15-45	45-90
RVE	Bow	77.9	8.9	21.5	22.2	12.9	13.7	14.5	6.3
	Port	177.3	9.6	16.2	17.3	15.2	16.1	18.3	7.3
	Starboard	311.8	8.2	18.9	22.9	15.6	16.6	12.7	5.1
	Aft	543.9	5.3	17.7	22.2	15.5	16.8	16.4	6.1
	Cloudy	285.5	6.3	17.7	20.8	15.3	17.6	15.2	7.1
	Total	1396.4	6.8	18.0	21.5	15.3	16.6	15.5	6.3
TVE	Bow	60.4	2.2	24.9	27.6	13.9	16.7	7.1	7.7
	Port	135.2	3.6	22.8	26.1	18.2	19.2	6.1	3.9
	Starboard	310.4	2.4	23.6	29.0	20.7	18.7	4.0	1.5
	Aft	610.5	1.8	23.4	29.4	19.9	20.9	4.0	0.6
	Cloudy	286.8	2.4	23.1	28.3	20.3	20.4	4.4	1.0
	Total	1403.3	2.3	23.4	28.7	19.8	20.0	4.4	1.5

Tests of Fit by Order of Model

Order	d.f.	Chi-square	p
0-Mean	69	1421748.38	<0.001
1	58	158746.91	<0.001
2	24	8854.22	<0.001
3	0	0.	1.

Tests of Partial Association

Source	d.f.	Chi-square	p
Sector	6	571633.38	<0.001
Sun	4	691340.75	<0.001
Team	1	27.92	<0.001
Sector by Sun	24	13314.36	<0.001
Sector by Team	6	128108.02	<0.001
Sun by Team	4	2760.09	<0.001
Sector by Sun by Team	24	8854.22	<0.001

Table 5. Percentage of total searching effort by team, sun location, and sector for the starboard binocular, 1983 cruise. Sector represents the degrees of arc searched, with 0 degrees being the trackline. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

			Sector (degrees)						
			Starboard				Port		
Team	Sun Position	Total Time (Hours)	90-180	45-90	15-45	0-15	0-15	15-45	45-90
RVE	Bow	72.8	13.3	23.8	21.5	11.2	9.0	15.1	6.2
	Port	151.3	9.8	21.5	24.3	18.4	13.2	10.9	2.0
	Starboard	285.2	13.0	19.4	16.7	15.0	16.6	16.3	3.0
	Aft	480.5	7.3	20.1	22.6	17.2	14.8	14.5	3.5
	Cloudy	255.8	9.3	19.4	20.9	19.1	16.4	12.6	2.4
	Total	1245.6	9.6	20.2	21.1	16.9	15.0	14.0	3.1
TVE	Bow	60.6	4.0	25.4	29.5	17.7	12.2	8.5	2.8
	Port	141.3	2.9	24.9	30.3	23.7	14.3	3.1	0.8
	Starboard	329.1	5.3	25.5	24.4	20.9	18.4	4.4	1.1
	Aft	610.5	3.0	22.8	28.4	24.0	17.3	3.5	0.9
	Cloudy	288.9	3.3	24.0	27.5	22.2	19.2	3.4	0.3
	Total	1430.4	3.6	24.0	27.5	22.7	17.5	3.8	0.9

Tests of Fit by Order of Model

Order	d.f.	Chi-square	p
0-Mean	69	1431923.50	<0.001
1	58	139712.75	<0.001
2	24	2780.02	<0.001
3	0	0.	1.

Tests of Partial Association

Source	d.f.	Chi-square	p
Sector	6	639838.88	<0.001
Sun	4	645851.44	<0.001
Team	1	6518.72	<0.001
Sector by Sun	24	22375.81	<0.001
Sector by Team	6	108226.28	<0.001
Sun by Team	4	5793.37	<0.001
Sector by Sun by Team	24	2780.02	<0.001

Table 6. Number of dolphin school sightings (row percentages in parentheses) by perpendicular distance to the trackline and sea state, 1982 cruise. Calm sea state is absence of white caps; rough sea state is presence of white caps. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

Team	Sea State	Perpendicular Distance (nautical miles)				
		0 - 0.5	0.5 - 1.0	1.0 - 2.0	2.0 +	Total
RVE	Calm	12 (44.4%)	2 (7.4%)	4 (14.8%)	9 (33.3%)	27
	Rough	36 (40.4%)	16 (18.0%)	19 (21.3%)	18 (20.2%)	89
	Total	48 (41.4%)	18 (15.5%)	23 (19.8%)	27 (23.3%)	116
TVE	Calm	6 (21.4%)	4 (14.3%)	10 (35.7%)	8 (28.6%)	28
	Rough	14 (33.3%)	10 (23.8%)	9 (21.4%)	9 (21.4%)	42
	Total	20 (28.6%)	14 (20.0%)	19 (27.1%)	17 (24.3%)	70

Tests of Fit by Order of Model

Order	d.f.	Chi-square	p
0	15	74.11	<0.001
1	10	16.28	0.092
2	3	2.69	0.442
3	0	0.	1.

Tests of Partial Association

Source	d.f.	Chi-square	p
Distance	3	14.36	0.003
Sea State	1	31.98	<0.001
Team	1	11.50	0.001

Table 7. Number of dolphin school sightings (row percentages in parentheses) by perpendicular distance to the trackline and sea state, 1983 cruise. Calm sea state is absence of white caps; rough sea state is presence of white caps. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

Team	Sea State	Perpendicular Distance (nautical miles)				
		0 - 0.5	0.5 - 1.0	1.0 - 2.0	2.0 +	Total
RVE	Calm	21 (41.2%)	7 (13.7%)	9 (17.6%)	14 (27.5%)	51
	Rough	35 (48.6%)	15 (20.8%)	9 (12.5%)	13 (18.1%)	72
	Total	56 (45.5%)	22 (17.9%)	18 (14.6%)	27 (22.0%)	123
TVE	Calm	18 (52.9%)	4 (11.8%)	7 (20.6%)	5 (14.7%)	34
	Rough	29 (65.9%)	8 (18.2%)	2 (4.5%)	5 (11.4%)	44
	Total	47 (60.3%)	12 (15.4%)	9 (11.5%)	10 (12.8%)	78

Tests of Fit by Order of Model

Order	d.f.	Chi-square	p
0	15	93.49	<0.001
1	10	13.43	0.200
2	3	1.72	0.632
3	0	0.	1.

Tests of Partial Association

Source	d.f.	Chi-square	p
Distance	3	65.09	<0.001
Sea State	1	4.80	0.029
Team	1	10.16	0.001

Table 8. Mean detection rates (sightings per hour of search effort) plus or minus one standard deviation (sample sizes in parentheses) by watch category, team, and sea state, 1982 cruise. Calm sea state is absence of white caps; rough sea state is presence of white caps. RVE: research-vessel experienced; TVE: tuna-vessel experienced. Short watches were less than 30 minutes long.

Watch	Team	Sea State	
		Calm	Rough
1-hour	RVE	0.66 ± 1.47 (30)	0.41 ± 0.84 (151)
	TVE	0.60 ± 1.16 (42)	0.18 ± 0.47 (125)
2-hour	RVE	0.73 ± 1.20 (11)	0.40 ± 0.67 (37)
	TVE	0.27 ± 0.45 (16)	0.14 ± 0.39 (34)
3-hour	RVE	0.14 ± 0.28 (4)	0.53 ± 0.59 (12)
	TVE	0.10 ± 0.21 (4)	0.26 ± 0.39 (13)
Short	RVE	0.62 ± 1.31 (15)	0.84 ± 1.72 (39)
	TVE	0.77 ± 1.46 (16)	0.44 ± 1.22 (51)

Source	Sum of Squares	d.f.	Mean Square	F	P
Watch (W)	5.14	3	1.71	1.86	0.136
Team (T)	2.18	1	2.18	2.36	0.125
Sea state (S)	0.44	1	0.44	0.48	0.488
W-T interaction	0.76	3	0.25	0.28	0.843
W-S interaction	2.92	3	0.97	1.05	0.368
T-S interaction	0.49	1	0.49	0.53	0.466
W-S-T interaction	1.47	3	0.49	0.53	0.662
Error	538.82	584	0.92		

Table 9. Mean detection rates (sightings per hour of search effort) plus or minus one standard deviation (sample sizes in parentheses) by watch category and team, first third of 1983 cruise. RVE: research-vessel experienced; TVE: tuna-vessel experienced. Short watches were less than 30 minutes long.

Watch	Team	
	RVE	TVE
1-hour	1.48 ± 1.94 (46)	0.62 ± 1.17 (54)
2-hour	0.97 ± 1.32 (17)	0.52 ± 1.01 (18)
3-hour	0.65 ± 0.81 (3)	0.13 ± 0.18 (5)
Short	1.73 ± 3.50 (20)	0.79 ± 1.73 (15)

Source	Sum of Squares	d.f.	Mean Square	F	P
Watch	7.73	3	2.58	0.78	0.507
Team	9.54	1	9.54	2.89	0.091
Interaction	1.44	3	0.48	0.15	0.932
Error	562.20	170	3.31		

Table 10. Mean detection rates (sightings per hour of search effort) plus or minus one standard deviation (sample sizes in parentheses) by team and sea state, 1983 cruise. Calm sea state is absence of white caps; rough sea state is presence of white caps. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

Team	Sea state	
	Calm	Rough
RVE	2.26 ± 2.99 (35)	0.39 ± 0.98 (235)
TVE	1.06 ± 1.50 (46)	0.16 ± 0.52 (229)

Source	Sum of Squares	d.f.	Mean Square	F	P
Team	34.76	1	34.76	27.18	<0.001
Sea state	128.77	1	128.77	100.66	<0.001
Interaction	16.09	1	16.09	12.58	<0.001
Error	692.09	541	1.28		

Table 11. Mean detection rates (sightings per hour of search effort) in the early part of 1-, 2-, and 3-hour watches combined versus the remainder of the watch. Mean detection rates were compared by a paired t-test.

Year	First 15 Minutes		Remainder of Watch		t	d.f.	p
	Mean	S.D.	Mean	S.D.			
1982	0.37	1.39	0.34	0.86	0.33	478	0.74
1983	0.68	3.49	0.44	1.12	1.56	450	0.12

Year	First 30 Minutes		Remainder of Watch		t	d.f.	p
	Mean	S.D.	Mean	S.D.			
1982	0.38	1.23	0.40	1.18	-0.21	472	0.83
1983	0.72	3.32	0.46	1.53	1.68	443	0.094

Table 12. Mean school size estimates plus or minus one standard deviation (sample sizes in parentheses) by observer and sea state, 1982 cruise. Analysis of variance was performed on log-transformed school size. Calm sea state is absence of white caps; rough sea state is presence of white caps. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

Team	Observer	Sea State	
		Calm	Rough
RVE	1	316 ± 464 (14)	195 ± 220 (44)
	4	201 ± 236 (16)	169 ± 185 (45)
	5	314 ± 379 (8)	219 ± 210 (23)
TVE	2	230 ± 207 (14)	164 ± 188 (29)
	3	280 ± 298 (15)	247 ± 258 (34)
	6	179 ± 173 (15)	262 ± 302 (30)

Source	Sum of Squares	d.f.	Mean Square	F	P
Observer	0.947	5	0.189	0.71	0.618
Sea State	0.389	1	0.389	1.45	0.229
Interaction	0.452	5	0.090	0.34	0.890
Error	73.643	275	0.268		

Table 13. Mean school size estimates plus or minus one standard deviation (sample sizes in parentheses) by observer and sea state, 1983 cruise. Analysis of variance was performed on log-transformed school size. Calm sea state is absence of white caps; rough sea state is presence of white caps. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

Team	Observer	Sea State	
		Calm	Rough
RVE	4	109 ± 130 (31)	113 ± 147 (50)
	7	115 ± 127 (31)	77 ± 106 (42)
	9	116 ± 133 (29)	89 ± 82 (42)
TVE	8	140 ± 157 (36)	144 ± 284 (45)
	10	127 ± 145 (36)	113 ± 172 (50)
	11	116 ± 139 (35)	118 ± 164 (42)

Source	Sum of Squares	d.f.	Mean Square	F	P
Observer	0.958	5	0.192	1.09	0.364
Sea State	0.378	1	0.378	2.15	0.143
Interaction	0.381	5	0.076	0.43	0.825
Error	80.251	457	0.176		

Table 14. Mean standardized differences between team school size estimates. Significance was determined with a one-sample t-test. Calm sea state is absence of white caps; rough sea state is presence of white caps. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

Year	Sea State	Mean	Std. Dev.	t	d.f.	p
1982	Calm	0.010	0.409	0.09	12	0.932
	Rough	0.216	0.715	1.71	31	0.097
1983	Calm	0.193	0.562	2.14	38	0.038
	Rough	-0.008	0.515	-0.11	47	0.910

Table 15. Number of previous cruise trips made by the observers selected for this study. RVE: research-vessel experienced; TVE: tuna-vessel experienced. Observer 4 (RVE team) was present on both the 1982 and 1983 cruises, and had therefore made 7 trips prior to the 1983 cruise.

Team	Observer	Year							Total (prior to 1982 cruise)
		1976	1977	1978	1979	1980	1981	1982	
RVE	1	1	1	0	1	0	0	0	3
	4	1	1	0	1	1	2	(1)	6
	5	0	0	0	0	3	0	0	3
	7	0	0	0	1	1	0	0	2
	9	0	0	0	0	1	0	0	1
TVE	2	0	0	1	1	2	2	1	7
	3	0	0	0	0	3	1	2	6
	6	0	0	1	1	1	2	1	6
	8	0	0	2	2	2	0	1	7
	10	0	0	0	0	1	1	0	2
	11	0	0	0	0	1	1	0	2

Table 16. Mean school size estimates made aboard commercial tuna vessels by the tuna-vessel experienced (TVE) observers selected for this study and all other tuna-vessel observers, 1978-1982. A one-sample t-test was performed on log-transformed school size.

Observer Group	Number of Sightings	Mean School Size	Standard Deviation	t (log size)	P
All non-TVE observers	14,358	634	998		
1982 TVE team	816	513	799	-3.95	<0.001
1983 TVE team	426	292	410	-9.71	<0.001

Table 17. Number of species identifications by team and sea state, 1982 cruise. Calm sea state is absence of white caps; rough sea state is presence of white caps. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

Team	Sea State	Species Identification?		
		No	Yes	Total
RVE	Calm	2 (4.3%)	44 (95.7%)	46
	Rough	1 (0.7%)	138 (99.3%)	139
	Total	3 (1.6%)	182 (98.4%)	185
TVE	Calm	4 (8.2%)	45 (91.8%)	49
	Rough	12 (11.5%)	92 (88.5%)	104
	Total	16 (10.5%)	137 (89.5%)	153

Tests of Fit by Order of Model

Order	d.f.	Chi-square	p
0	7	410.36	<0.001
1	4	18.01	0.001
2	1	2.78	0.095
3	0	0.	1.

Tests of Partial Association

Source	d.f.	Chi-square	p
Identification (ID)	1	322.27	<0.001
Sea State	1	67.05	<0.001
Team	1	3.03	0.082
ID by Sea State	1	0.00	0.95
ID by Team	1	12.99	<0.001
Sea State by Team	1	2.01	0.16

Table 18. Number of species identifications by team and sea state, 1983 cruise. Calm sea state is absence of white caps; rough sea state is presence of white caps. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

Team	Sea State		Species Identification?		
			No	Yes	Total
RVE	Calm		4 (3.6%)	107 (96.4%)	111
	Rough		13 (8.0%)	150 (92.0%)	163
		Total	17 (6.2%)	257 (93.8%)	274
TVE	Calm		8 (6.7%)	112 (93.3%)	120
	Rough		19 (12.7%)	131 (87.3%)	150
		Total	27 (10.0%)	243 (90.0%)	270

Tests of Fit by Order of Model

Order	d.f.	Chi-square	p
0	7	469.54	<0.001
1	4	8.59	0.072
2	1	0.003	0.86
3	0	0.	1.

Tests of Partial Association

Source	d.f.	Chi-square	p
Identification	1	448.50	<0.001
Sea State	1	12.41	<0.001
Team	1	0.03	0.86

Table 19. Relative frequency of individual species identified by team and sea state, 1982 cruise. Mixed schools contained both spotted and spinner dolphin. Calm sea state is absence of white caps; rough sea state is presence of white caps. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

Team	Sea State	Species						
		Spotted	Spinner	Common	Striped	Mixed	Other	Total
RVE	Calm	13 (32.5%)	0 (0.0%)	5 (12.5%)	5 (12.5%)	13 (32.5%)	4 (10.0%)	40
	Rough	35 (26.3%)	11 (8.3%)	15 (11.3%)	16 (12.0%)	47 (35.3%)	9 (6.8%)	133
	Total	48 (27.7%)	11 (6.4%)	20 (11.6%)	21 (12.1%)	60 (34.7%)	13 (7.5%)	173
TVE	Calm	10 (23.3%)	2 (4.7%)	3 (7.0%)	9 (20.9%)	19 (44.2%)	0 (0.0%)	43
	Rough	19 (20.7%)	7 (7.6%)	14 (15.2%)	18 (19.6%)	31 (33.7%)	3 (3.3%)	92
	Total	29 (21.5%)	9 (6.7%)	17 (12.6%)	27 (20.0%)	50 (37.0%)	3 (2.2%)	135

Tests of Fit by Order of Model

Order	d.f.	Chi-square	p
0	23	221.08	<0.001
1	16	23.94	0.091
2	5	7.21	0.21
3	0	0.	1.

Tests of Partial Association

Source	d.f.	Chi-square	p
Species	5	124.43	<0.001
Sea State	1	68.01	<0.001
Team	1	4.70	0.003

Table 20. Relative frequency of individual species identified by team and sea state, 1983 cruise. Mixed schools contained both spotted and spinner dolphin. Calm sea state is absence of white caps; rough sea state is presence of white caps. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

Team	Sea State	Species						
		Spotted	Spinner	Common	Striped	Mixed	Other	Total
RVE	Calm	15 (14.7%)	5 (4.9%)	22 (21.6%)	26 (25.5%)	20 (19.6%)	14 (13.7%)	102
	Rough	32 (22.2%)	11 (7.6%)	48 (33.3%)	35 (24.3%)	13 (9.0%)	5 (3.5%)	144
	Total	47 (19.1%)	16 (6.5%)	70 (28.5%)	61 (24.8%)	33 (13.4%)	19 (7.7%)	246
TVE	Calm	23 (20.9%)	10 (9.1%)	25 (22.7%)	23 (20.9%)	18 (16.4%)	11 (10.0%)	110
	Rough	33 (25.4%)	10 (7.7%)	40 (30.8%)	26 (20.0%)	15 (11.5%)	6 (4.6%)	130
	Total	56 (23.3%)	20 (8.3%)	65 (27.1%)	49 (20.4%)	33 (13.8%)	17 (7.1%)	240

Tests of Fit by Order of Model

Order	d.f.	Chi-square	p
0	23	146.78	<0.001
1	16	27.83	0.033
2	5	2.59	0.76
3	0	0.	1.

Tests of Partial Association

Source	d.f.	Chi-square	p
I	5	110.94	<0.001
S	1	7.93	0.005
T	1	0.07	0.79
I,S	5	21.53	0.001
I,T	5	2.99	0.70
S,T	1	1.16	0.28

Table 21. Mean estimates of the proportions of species within schools plus or minus one standard deviation (sample sizes in parentheses) by team, 1982 cruise. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

Team	Observer	Species				
		Spotted	Spinner	Common	Striped	Other
RVE	1	.67 ± .38 (45)	.47 ± .39 (31)	1.00 ± 0.0 (7)	.92 ± .20 (6)	.44 ± .41 (7)
	4	.66 ± .37 (50)	.51 ± .35 (32)	.94 ± .17 (9)	.98 ± .06 (12)	.49 ± .44 (9)
	5	.82 ± .25 (20)	.49 ± .35 (13)	1.00 ± 0.0 (4)	1.00 ± 0.0 (3)	.77 ± .37 (8)
TVE	2	.68 ± .30 (24)	.49 ± .32 (19)	1.00 ± 0.0 (6)	1.00 ± 0.0 (10)	.98 (1)
	3	.68 ± .30 (28)	.51 ± .27 (19)	1.00 ± 0.0 (7)	1.00 ± 0.0 (8)	.55 ± .64 (2)
	6	.71 ± .29 (28)	.48 ± .33 (22)	1.00 ± 0.0 (4)	1.00 ± 0.0 (9)	.53 ± .67 (2)
Kruskal-Wallis Statistic		4.036	0.619	3.111	4.173	3.100
p		0.54	0.99	0.68	0.53	0.69

Table 22. Mean estimates of the proportions of species within schools plus or minus one standard deviation (sample sizes in parentheses) by team, 1983 cruise. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

Team	Observer	Species				
		Spotted	Spinner	Common	Striped	Other
RVE	4	.72 ± .35 (34)	.63 ± .36 (18)	.93 ± .17 (28)	.94 ± .16 (24)	.60 ± .40 (10)
	7	.74 ± .34 (28)	.55 ± .34 (18)	.91 ± .22 (27)	.90 ± .23 (21)	.69 ± .38 (10)
	9	.83 ± .25 (22)	.62 ± .39 (16)	.95 ± .16 (21)	.92 ± .23 (18)	.57 ± .44 (9)
TVE	8	.79 ± .31 (33)	.60 ± .33 (19)	.99 ± .06 (22)	.99 ± .05 (20)	.64 ± .41 (7)
	10	.76 ± .33 (33)	.67 ± .33 (19)	.96 ± .12 (24)	.97 ± .10 (17)	.66 ± .32 (8)
	11	.81 ± .32 (26)	.71 ± .33 (18)	.97 ± .09 (19)	.97 ± .12 (12)	.69 ± .27 (8)
Kruskal-Wallis Statistic		3.594	2.566	5.133	2.585	0.385
p		0.61	0.77	0.40	0.76	0.99

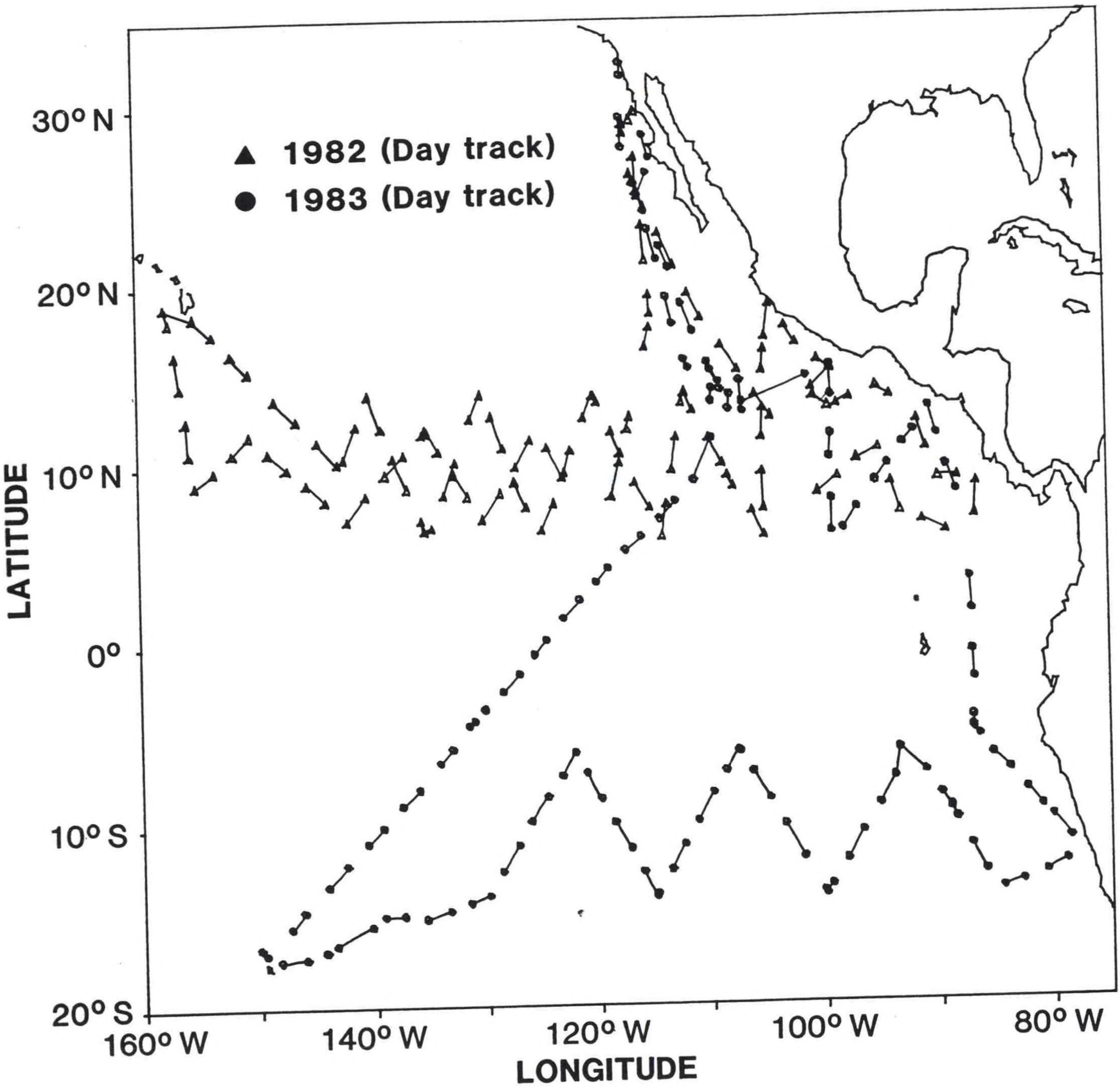

Figure 1. Cruise tracks for 1982 (triangles) and 1983 (circles) research cruises. The lines adjoining symbols represent searching effort, while spaces between lines represent no effort (usually distance covered at night).

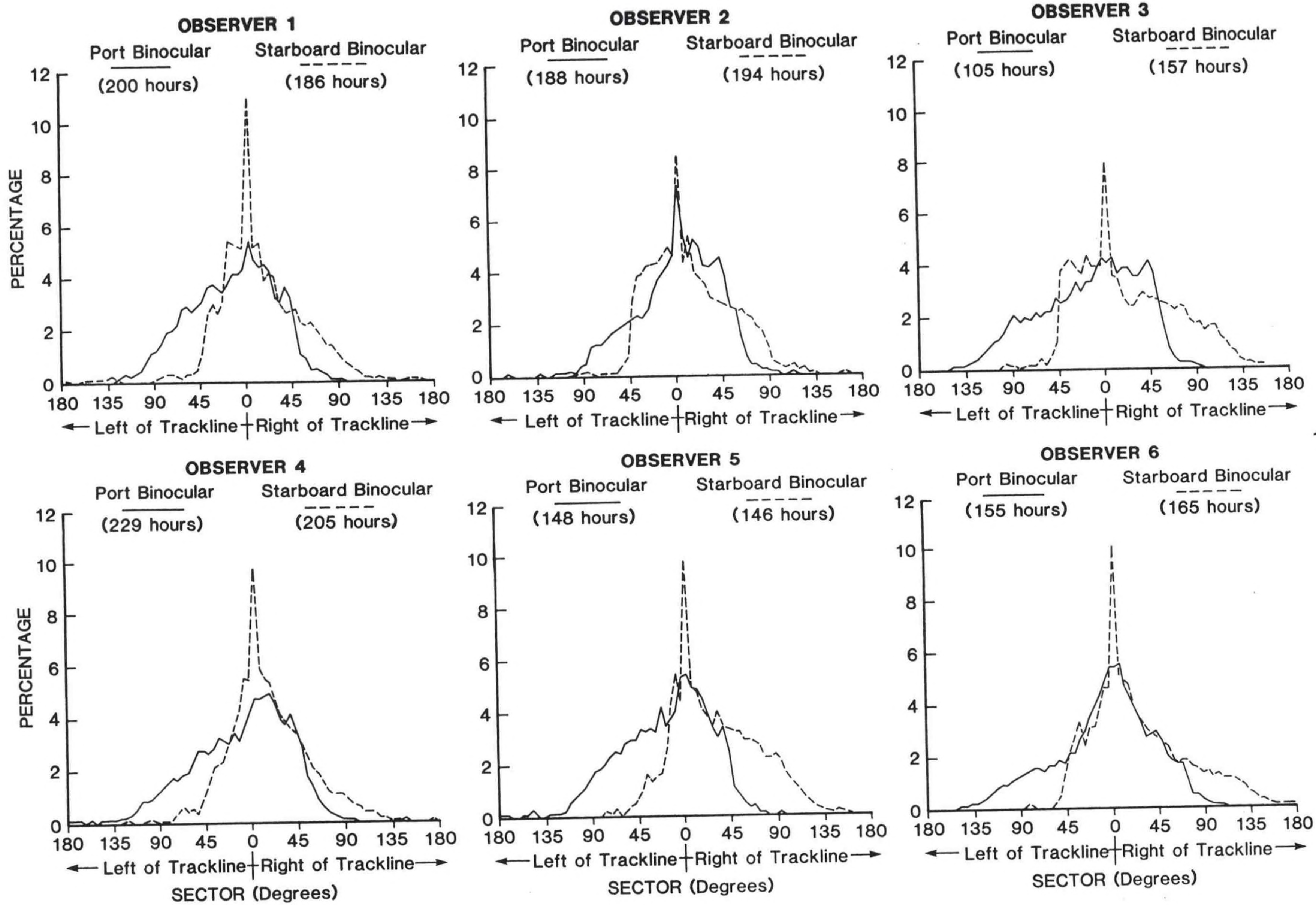

Figure 2. Frequency distributions of searching effort through port (____) and starboard (----) binoculars by all observers, 1982 cruise. Effort was recorded for each 5° segment of arc.

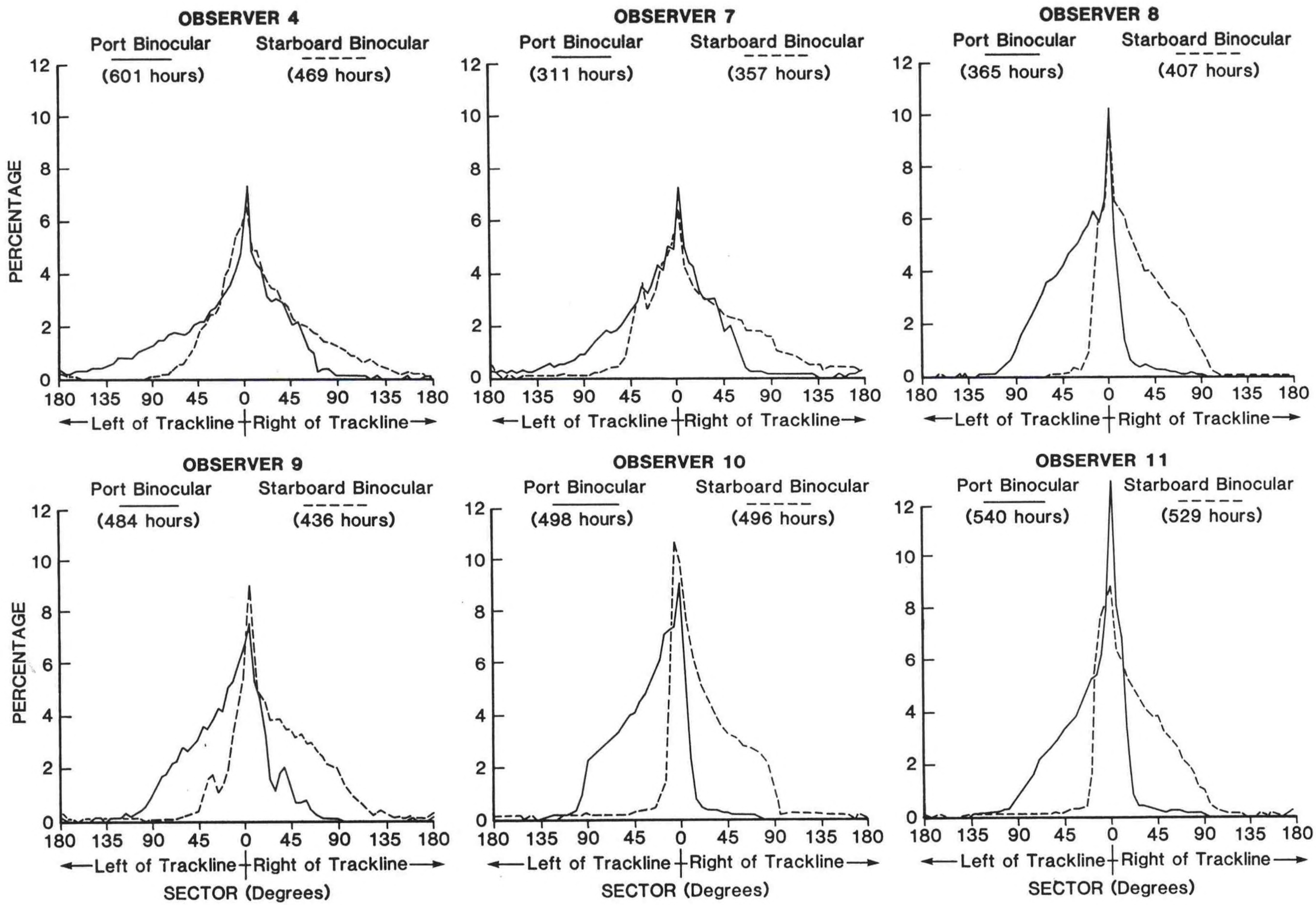

Figure 3. Frequency distributions of searching effort through port (____) and starboard (----) binoculars by all observers, 1983 cruise. Effort was recorded for each 5° segment of arc.

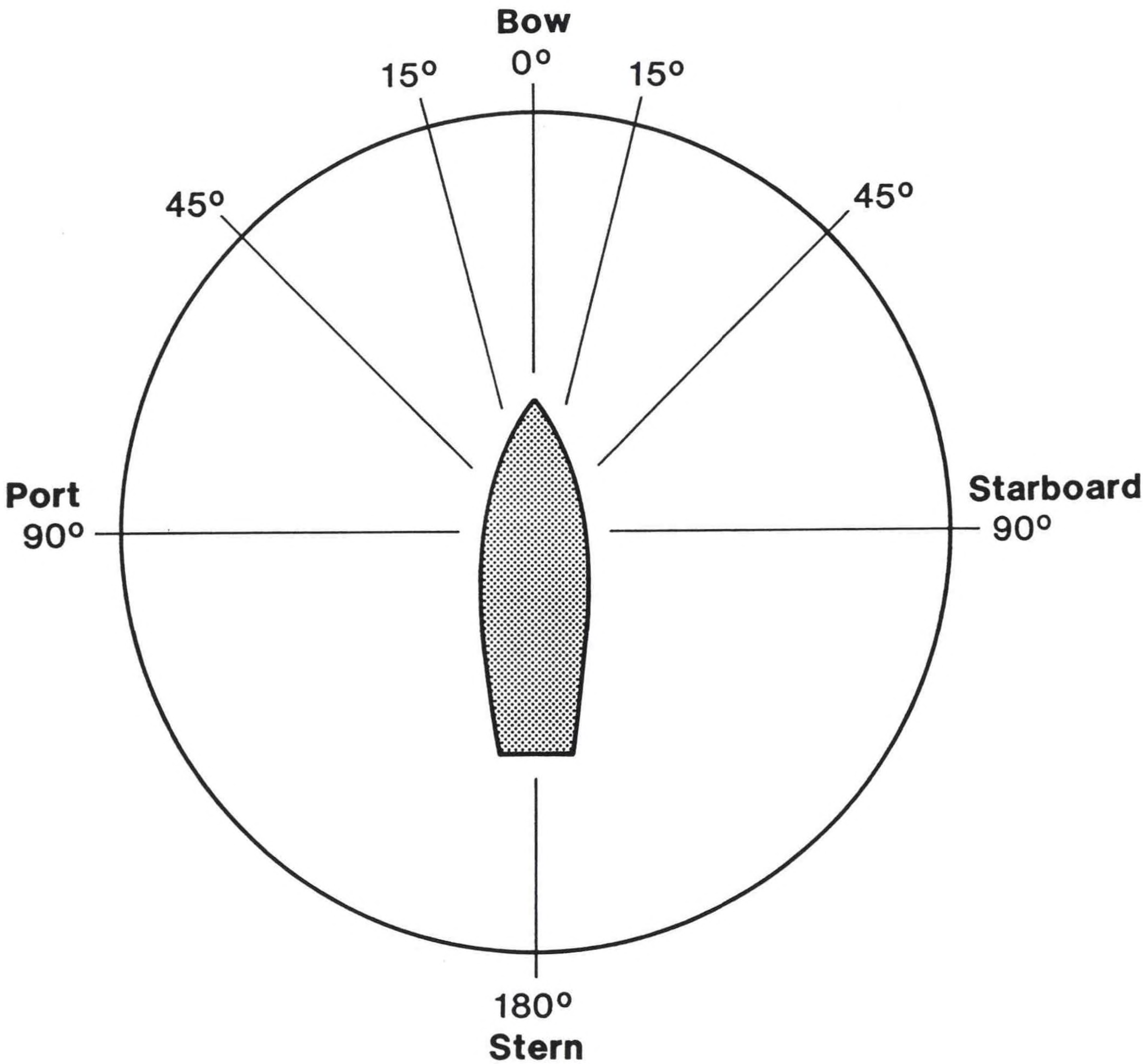

Figure 4. Sections of searching arc used for searching pattern analyses. The 5° sectors were grouped into 0°-15°, 15°-45°, 45°-90°, and 90°-180° from the trackline on each side of the ship.

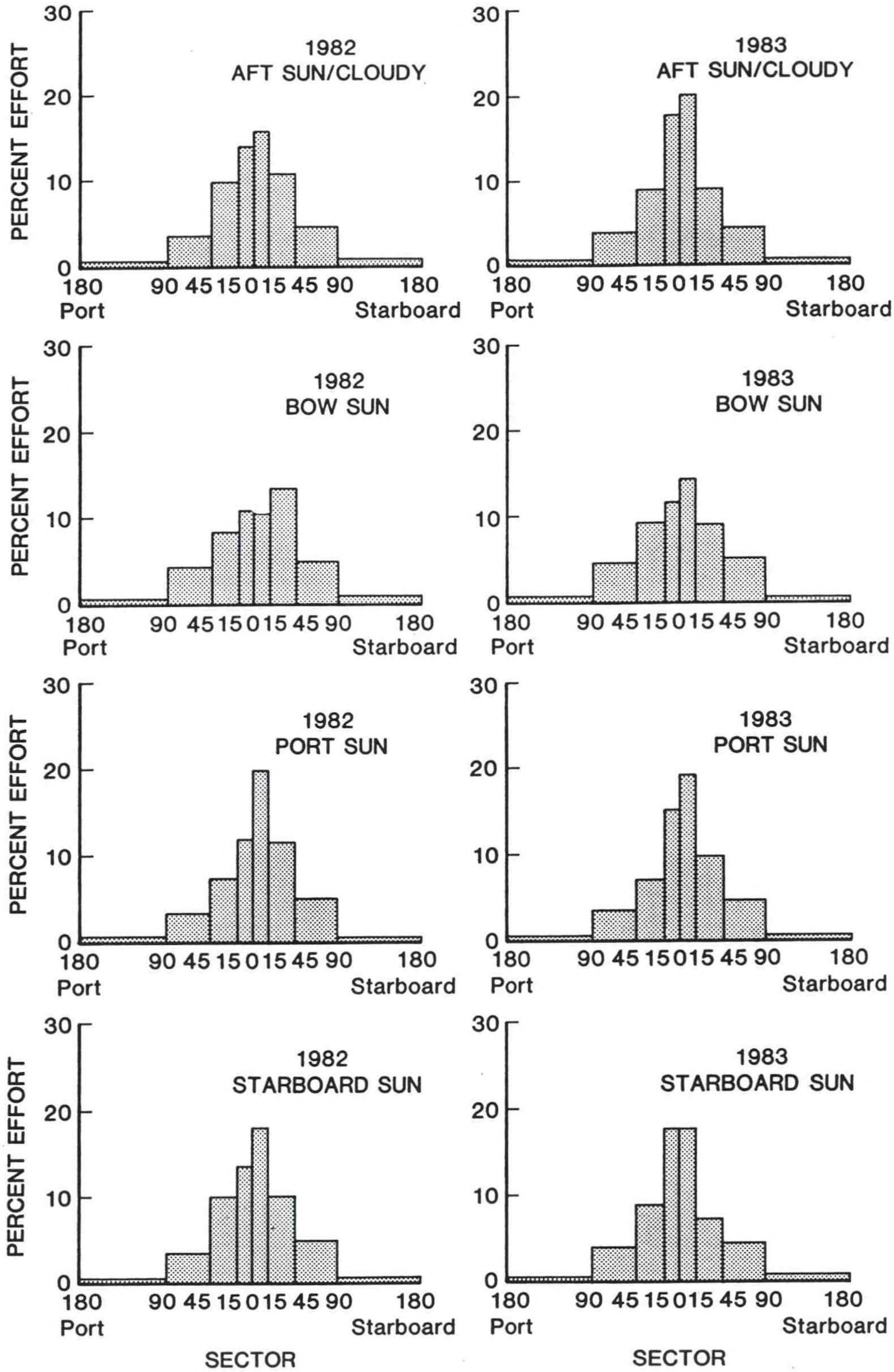

Figure 5. Frequency distributions of searching effort by sun position for all observers with port and starboard effort combined. Aft Sun/Cloudy is sun overhead, behind, or obscured by clouds; Bow Sun is sun directly in front of the ship; Port Sun is sun to the port side of the bow; Starboard Sun is sun to the starboard side of the bow.

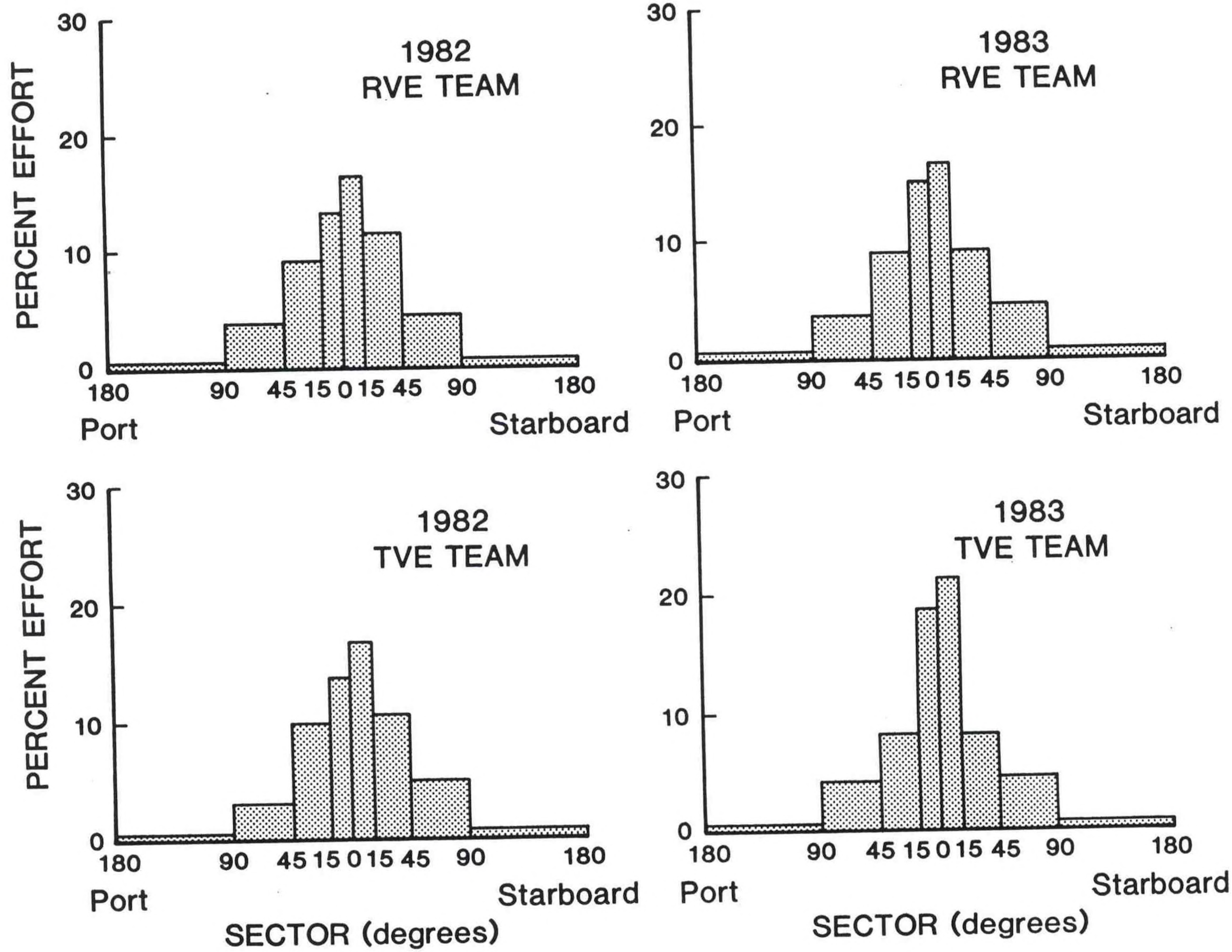

Figure 6. Frequency distributions of searching effort by team with port and starboard effort combined. RVE: research-vessel experienced; TVE: tuna-vessel experienced.

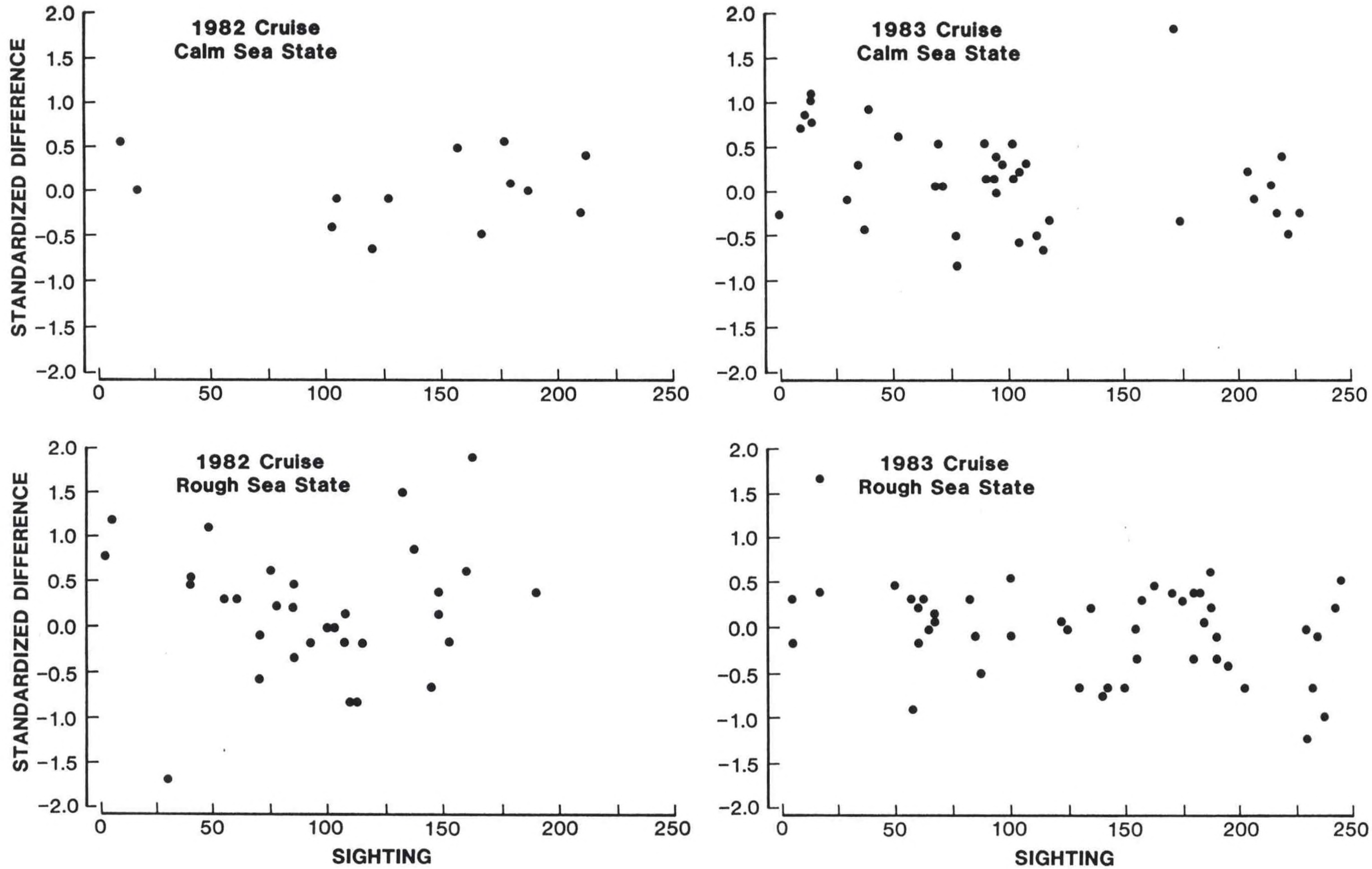

Figure 7. Standardized differences between mean school size estimates of the two teams. Rough sea state is presence of white caps; calm sea state is absence of white caps.