THE TUNA/PORPOISE PROBLEM: DEDICATED VESSEL RESEARCH PROGRAM

Summary of Research Results from the Second Leg of the Third Cruise of the Dedicated Vessel
20 July to 18 August 1978

III_2

by

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ABSTRACT

The National Marine Fisheries Service, the Marine Mammal Commission, and the United States Tuna Foundation sponsored the tuna seiner M/V Queen Mary during 1978 as a "dedicated vessel" to study the tuna/porpoise problem. Between 20 July and 18 August, the focus of the research was two-fold: porpoise behavior and tuna olfactory attractants.

Seventeen porpoise sets were made, more than 5600 were captured, 49 tons of tuna were captured, and three porpoise were killed.

The behavioral investigators, using the focal animal sampling method, made most of their observations while swimming among the porpoise. With the focal animal sampling method, single animals were observed for 5 minutes, and all of their overt behavior was recorded on slates. A total of 135 5-minute case observations was made. A "dictionary" of behavioral events occurring in the purse seine was developed so the patterns can be recognized by others. The composition and sizes of various porpoise subgroups were identified. A number of behavioral responses thought to be learned were observed and noted. A composite behavioral sequence for a typical set on this cruise is described.

The tuna olfactory attractant was tested on 10 sets. A response from the tuna was observed on only two sets. On one set, a few individuals reacted briefly; however, no response was seen from the whole school. On the other set, 2 tons of tuna responded to the attractant for short periods of time; however, the school did not stay near the attractant for long periods.

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I. INTRODUCTION

The Dedicated Vessel Program is a cooperative tuna/porpoise research program under the joint direction of the Marine Mammal Commission (MMC), the National Marine Fisheries Service (NMFS), and the United States Tuna Foundation (USTF). The USTF chartered the commercial tuna seiner, M/V Queen Mary, to be used as a platform for that research during 1978. NMFS, USTF, MMC, and the National Science Foundation (NSF) provided research funds and/or support.

The Dedicated Vessel Program research plan provided for five cruises of 50 days each. The goals were to: 1) develop and refine fishing gear or procedures to further reduce the incidental mortality rate and 2) provide demographic and biological data needed to better assess the impacted porpoise stocks. Proposals for relevant research were accepted from all interested persons and organizations. The NMFS and USTF provided research funds for Cruise III, Leg 2, of the Dedicated Vessel. Mr. David Bratten, NMFS, was the Cruise Leader. Other scientific personnel were: Mr. Andrew Brittain, University of Hawaii; Mr. Walter Ikehara, University of Hawaii; Ms. Ingrid Kang, Sea Life Park; Ms. Karen Pryor, New York University; and Mr. Philippe Vergne, Living Marine Resources.

This report summarizes the research conducted during Cruise III, Leg 2. It was compiled from cruise reports submitted to the Program Manager. David Bratten submitted a report on gear dynamics, Walter Ikehara submitted a report on the tuna olfactory attractant, Karen Pryor submitted a report on the behavior of captured porpoise, and Philippe Vergne submitted a report on the behavior of porpoise schools and general tuna behavior.

The findings and conclusions of this paper are preliminary and are by no means a final summary of porpoise behavioral observations made on this cruise by Pryor and Kang. It is not feasible within the scope of this report to provide all the quantitative data substantiating the conclusions; so while overall trends are evident, confirmatory data await a more detailed analysis. These findings, therefore, represent the conclusions of the investigators based on their familiarity with an extensive body of data which is still being processed. These preliminary findings will be, of course, subject to further amplification and modification. Behavioral terminology in the text is based on DeFran and Pryor, (in press) 1979.[1] Brief definitions of behavioral terms are given in Appendix A of this report.

[1] Behavior and Training of Cetacean in Captivity. R.H. DeFran, Dept. of Psychology, SDSU, and K. Pryor, Dept. of Biology, NYU, will be a chapter in "Cetacean Behavior," Louis Herman, Editor, Wiley-Interscience (in press)

Other reports from this cruise are planned. Karen Pryor will submit a contract report to NMFS and plans to publish several other papers on her observations of the behavior of captured porpoise. Walter Ikehara will submit a contract report to NMFS on tuna olfactory attractants. Philippe Vergne plans to publish his observations of the composite behavior of porpoise schools and tunas.

The scientific party would like to thank the Captain, Ralph Silva, Jr., and the crew of the Queen Mary for their helpful suggestions, assistance, and total cooperation during the cruise. A special thanks is given to Ralph Silva, III, for standing a shark watch during the underwater behavioral observations.

The second leg of Cruise III was a 30-day trip. The Queen Mary left San Diego on 20 July 1978 and returned on 18 August 1978.

The area of research operation was the yellowfin tuna fishing grounds off Mexico and Central America, both inside and outside the Inter-American Tropical Tuna Commission Regulatory Area (CYRA). The cruise track is shown in Figure 1.

II. VESSEL AND EQUIPMENT

The M/V Queen Mary, built in 1969, is 151 feet long, has a 34-foot beam and a 17-foot draft. She is propelled by twin Caterpillar diesel engines, 1125 horsepower each, that provide a maximum speed of 12.5 knots. The vessel is equipped with a Caterpillar 333 bowthruster, a Marco #W1062 main winch, and a 42" power block. The vessel can carry from 520 to 550 tons of tuna, depending on fish size, in seven pairs of brine wells and one pair of stern boxes. The net used during the cruise was 560 fathoms long, 11 strips[1/] deep with 190 fathoms of double-depth safety panel (1¼-mesh) and a super apron.

III. OBJECTIVES

The primary goals of this cruise were: (1) to make detailed observations of porpoise behavior; (2) to test tuna olfactory attractants; and (3) to observe and record purse seine gear dynamics. Ancillary goals were developed to take advantage of all research opportunities.

A. Observations of Porpoise Behavior

The goals of this study were to:

1. Make detailed observations of the behavior of captured porpoise[2/]. Specifically the observers were to:

    a. Determine and describe porpoise behavior patterns

[1/] A standard strip of webbing is one hundred (4¼-inch) meshes deep.

[2/] These observations were made and reported by Pryor and Kang.

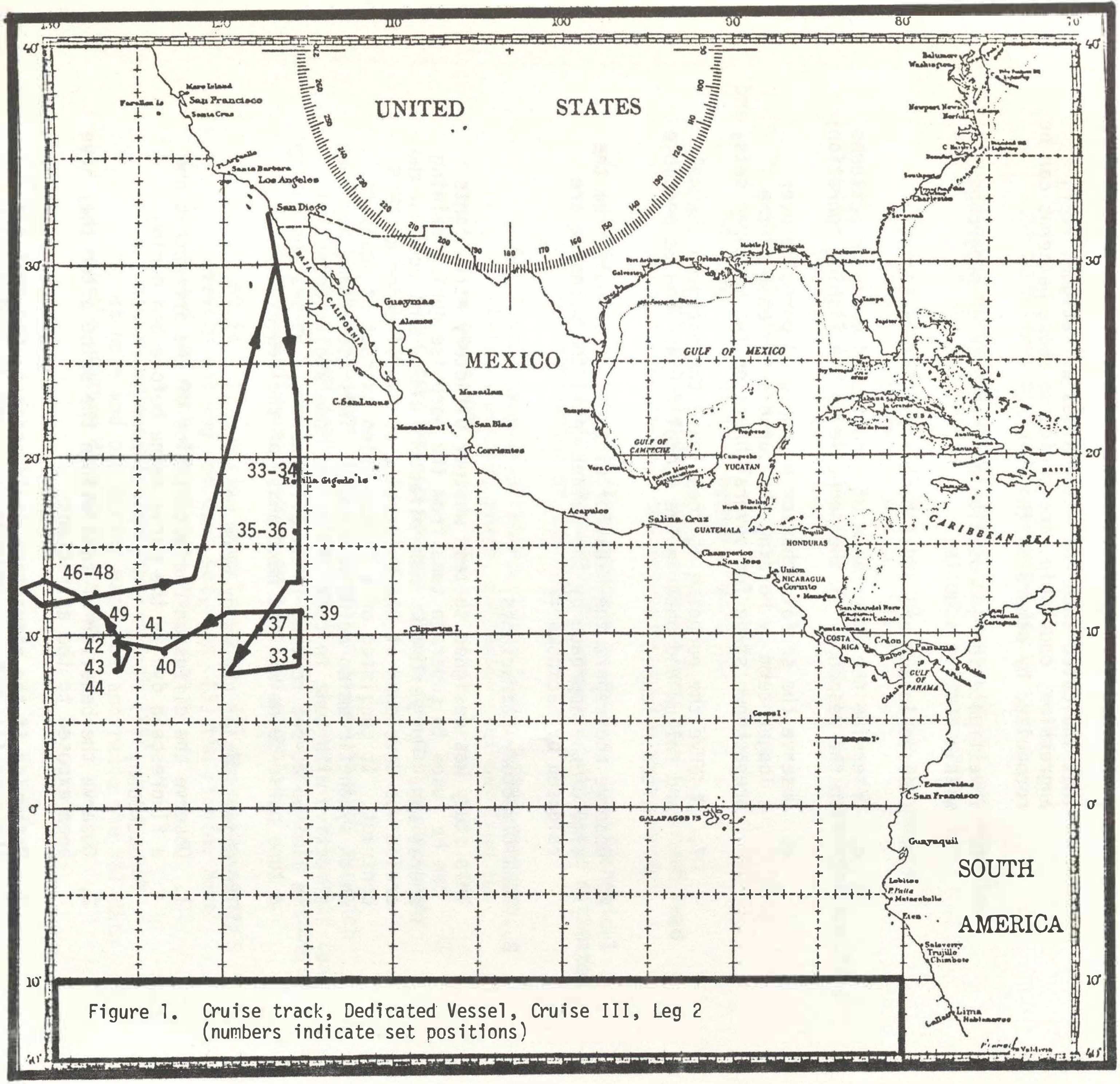

Figure 1. Cruise track, Dedicated Vessel, Cruise III, Leg 2
(numbers indicate set positions)

that indicated such characteristics as fatigue, fear, aggression, courtship, and panic, so these patterns can be recognized by others in the future;

b. Investigate the composition and behavior of subgroups within captive schools;

c. Observe infant and adult behavioral interactions;

d. Determine the importance of conditioned behavior patterns in the responses of the porpoise to the fishing operation;

e. Observe the social behavior of captured porpoise over a longer term by holding the purse seine open at the prebackdown stage for several hours on two or three sets, and

f. Observe the porpoise as they leave the backdown channel, and follow and observe the school for as long as possible after release.

2. Observe and report the behavior of porpoise schools from the time of the approach by the seiner until the porpoise are released by backdown.[1/]

B. Tuna Olfactory Attractants

This study was designed to test whether olfactory attractants can be used to separate tuna from the porpoise during seining operations. The yellowfin tuna olfactory attractant used on the cruise was developed at the University of Hawaii under an NMFS contract. It consisted of a freeze-dried extract of squid to which synthetic amino acids were added. This attractant had been effective with tuna in tank tests and moderately successful in limited at-sea testing in Hawaiian waters. At-sea testing in a tuna purse seine was the next phase of the research.[2/]

The objectives of the study were to:

1. Observe the diffusion characteristics of the attractant and a fluorescein dye in the purse seine before and during backdown;

2. Observe the behavior of tuna within the seine after they have been exposed to the attractant;

3. Determine if the attractant could separate the tuna and the porpoise; and

4. Observe the behavior of tuna associated with porpoise within the seine.[1/]

[1/] These observations were made and reported by Vergne.

[2/] This research was conducted by Ikehara.

C. Purse Seine Gear Dynamics[1/]

The objectives of this study were to:

1. Make detailed observations of the causes of and remedies for net collapses;

2. Make systematic observations of stern sway and canopy formation before and during backdown; and

3. Measure the linear distance from the vessel to several specific points on the corkline.

D. Ancillary Research[1/]

The objectives of this research were to:

1. Collect the standard NMFS life history data from each dead porpoise and collect the following biological samples:

   a. An eye (the eye-lens protein to be used for biochemical age estimation which will be compared to the age estimated by examination of the teeth);

   b. Tissue samples of heart, lung, liver, kidney, spleen, skeletal muscle, brain, and melon sections from ten animals; and

   c. Blood samples and adrenal glands for capture myopathy studies;

2. Collect stomachs from all porpoise killed in sets in which five or more porpoise died and flag at least 40 yellowfin tuna captured in any such set, so the tuna stomachs can be recovered later for dietary studies on tuna and porpoise;

3. Maintain (1) a marine mammal watch, (2) the standard NMFS research set log for each set, and (3) the Fishing Mode Record for each day at sea; and

4. Launch an expendable bathythermograph (XBT) probe each day at noon and one during each set and radio the XBT data and the weather data daily to WWD.

IV. METHODS

A. Observations of Porpoise Behavior

1. Behavior observations of captured porpoise[2/]

The two methods of collecting data used were ordinary field notes (either written or recorded on tape) and a system borrowed

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[1/] This research was conducted by Bratten.

[2/] Pryor and Kang.

from primate research called Focal Animal Sampling. This latter method consists of observing single animals, one at a time, and recording all overt behavior that occurs within a given time. For this study a 5-minute time period was selected. Careful selection of focal animals permitted observations of both the major activities and subtle behavioral events.

Prior to the cruise, a data acquisition system was devised so that information from focal animal observations could be entered as computer data for later analysis. A list of about 100 behavioral events known to occur in spinner and spotter porpoises was compiled into a "behavioral dictionary" (Appendix A). Each item was assigned a two-letter, one-digit mnemonic code. These codes were then used as a shorthand device to record data at sea.

Observations were made and recorded underwater by snorkeling researchers writing on sanded Lucite slates with lead pencils. Most of the porpoise that were observed underwater were observed from a distance of 30 feet or less. The bulk of the information was collected while snorkeling within 5 feet of the porpoise. After each dive, behavioral and demographic data for each focal case animal were transferred to data forms, and general field notes were taped or logged. It was essential that the investigators be free-swimming and, when possible, unencumbered by safety lines or other gear so that the animals could be observed and followed freely over a prolonged period of time.

Surface observations were also made but were found to have extreme limitations. Most behavioral events cannot be observed from the surface, and what can be observed often is difficult to interpret (see discussion).

The behavioral team attempted to start observing the porpoise as soon after encirclement as possible. The procedure that proved most efficient follows:

- A four-man, motorized raft was launched from the starboard side (i.e., opposite side from the net) of the vessel after the net skiff started towing, and the observation team entered the raft, circled the bow, and went over the corkline into the net.

- Behavioral observations were made by three free-diving observers. One of the observers was equipped with a bang stick and watched for sharks, and one other person watched for sharks from the surface.

- After rings up, a crewman equipped with a bang stick went into the net in a two-man raft and free-dove with the observers. Thus, after rings up, there were three people on shark watch (two in the water and one in a raft) while two others made observations of the captive porpoise.

The behavioral observations of captured porpoise and tuna were generally made by divers swimming among the porpoise. The observations of the tuna reactions to the olfactory attractant (methods to be described later) were made from a raft. The primary concern during the cruise was for the safety of divers. Whenever divers were in the water, two or three people were on shark watch (one or two in the water and one in a raft). Fortunately, few sharks were encountered during the cruise, and the presence of sharks hindered underwater observations in only one set. Whenever the attractant was being pumped, the divers would leave the water because its effect on sharks was unknown.

2. General behavioral observations of the porpoise school during the set sequence[1/]

Surface behavioral observations were collected on whole schools with emphasis on their reaction as a cohesive unit. The set sequence was separated into the following six phases, and the time that each phase started was recorded in the set log.

a. Prechase covered the time of sighting of birds or porpoise on the surface until speedboat launch.

b. Chase covered the time from speedboat launch until net-skiff release.

c. Setting and pursing covered net-skiff release until the net was completely pursed and the rings were on the stripper.

d. Rolling the net covered the time from the start of rolling and stacking the net until the net was tied down for backdown.

e. Backdown covered net tie-down to backdown completion.

f. Post-backdown covered backdown completion until the skiff was aboard the seiner again.

After sighting the birds or porpoises, behavioral observations were made from the 20-power binoculars atop the pilot house until the speedboats were launched. During the chase, observations were made from the crosstrees on the mast, a vantage point above the porpoise school, the working speedboats, and the seiner. From the time pursing started until after backdown, underwater observations were made as previously described.

1/ Vergne

During hand-rescue operations at backdown, observations were made from a raft or by swimmers. After backdown, observations were made from a rubber raft or from the seiner.

B. Tuna Olfactory Attractants[1/]

During two phases of the purse seine operation, three types of experimental treatments were planned: control tests, tests with attractant alone, and tests with attractant and a fluorescein dye combined. The tests were to be conducted before or during backdown. There was enough attractant for 15 tests.

All tests began after rings-up. Pre-backdown tests began approximately 20 minutes before backdown; tests before and during backdown began about 5 minutes before backdown; and tests during backdown began as soon as the backdown tiedown point was reached.

The freeze-dried squid extract and the amino acids were mixed with sea water in two 50-gallon drums on the port side of the vessel, and the mixture was pumped into the net through a garden hose. The two observers, towing the weighted end of the hose, paddled into the net in a small rubber raft. When the raft was 15 to 20 meters from the vessel, the observers dropped the end of the hose and tried to keep it about one meter above the net bottom. A hand signal directed pumping. The observers, using masks and snorkels, made observations and took photographs from the side of the raft.

C. Purse Seine Gear Dynamics[2/]

The severity and treatment of all net collapses were recorded as the collapses occurred. Porpoise involvement, the configuration of the backdown channel and any formation of stern sway or canopies were observed on every set.

Measurements of the distance to specific points on the corkline from the vessel were made at five times during the set: (1) when the stern end of the net arrived at the vessel, (2) when the net was one-half pursed, (3) when the rings were up, (4) when backdown started, and (5) when backdown terminated. The measurements were made with a Leitz rangefinder. Buoys were used to mark the points on the corkline.

D. Ancillary Research[2/]

The standard NMFS life history form was completed for all the dead animals. Samples of an eye, liver, spleen, heart, kidney, and adrenal glands were collected, quick frozen, and stored at -60°C. Post-mortem blood samples were also collected.

1/ Ikehara

2/ Bratten

A marine mammal watch was maintained during the daylight hours. The set logs were completed for each set, and a record of the vessel's activities was kept for each day at sea.

An XBT was launched each day at noon and another during each set when possible. The XBT and local weather data was sent by radio to WWD on a daily basis, when possible.

V. RESULTS

Seventeen sets were made during the cruise, all on porpoise schools (Table 1). More than 5600 porpoises were captured, and 44 tons of yellowfin (*Thunnus albacares*) and five tons of skipjack tuna (*Katsuwonus pelamis*) were loaded. Six sets were made on pure schools of spotted porpoise (*Stenella attenuata*), and 11 sets were made on mixed schools of spotters and spinners (*Stenella longirostris*). Three offshore spotters died.

A. Observations of Porpoise Behavior

1. Behavior observations of captured porpoise 1/

A total of 134 5-minute case observations were recorded (Table 2). Twelve cases were recorded on whole schools and 122 on single animals or mother-infant pairs. Both spotter and spinner porpoise were studied. Extensive anecdotal material was recorded and will appear in an NMFS contract report and subsequent publications.

a. Individual behavior

Many of the approximately 100 behavioral events selected for computer coding occurred in the net. Some behavioral events, such as nursing 2/ and copulation 3/, which have been reported by others as occurring the seine, were not observed on this cruise. Many fear and stress signals which were anticipated were in fact rare or not observed. Seven behavioral events were observed which had not been recorded in captivity; most of these were forms of mother and young interaction. Many episodes of play, courtship, status conflicts and other normal forms of porpoise social interaction were recorded both in focal animal samples and in general field observations. A list of behavioral events observed in both spotters and spinners in captivity and in the purse seine is given in Appendix A.

1/ Pryor and Kang

2/ Norris, K.S., W.E. Stuntz, W. Rogers, The Behavior of Porpoises and Tuna in the Eastern Tropical Pacific Yellowfin Tuna Fishery, Preliminary Studies. Center for Coastal Marine Studies, Univ. of California, Santa Cruz, California 95064, February 1978.

3/ Personal communication from skippers and crew

Table 1. Summary of set data

Set #	Date	Latitude	Longitude	Time Set	Total Chase Time (Min)	Estimated Number Captured				Total Backdown Time (Minutes)	Total @/ Killed	Total Tons	Research	
						Spotted	Eastern Spinner	White Belly Spinner	Total				Number of Behavioral Cases Observed	Olfactory Attractant Test
033	7/23	19°33'N	115°25'W	1247	11	20			20	7	0	0	2	Not tested
034	7/23	19°22'N	115°25'W	1539	9	85			85*	9	0	3	2**	Dye before BD
035	7/24	16°30'N	115°45'W	0943	54	58			58	5	0	1	10	Dye before BD
036	7/24	16°15'N	115°41'W	1310	10	25			25	7	0	2	8	Not tested
037	7/28	10°40'N	117°31'W	0723	11	25	100		125	7	0	0	19	Not tested
038	7/30	08°42'N	115°16'W	1747	49	215			215	7	0	4	6†	Before BD
039	8/01	11°58'N	115°28'W	1439	18	300	550		850	14	2	1	Aborted	Not tested
040	8/03	09°14'N	123°10'W	1133	14	245	30		275	10	0	6	1**	Before BD
041	8/04	09°58'N	125°38'W	1228	66	320		80	400	9	0	9	6	Before & during BD
042	8/05	09°51'N	126°00'W	1144	26	295		355	650	7	0	2	35	During BD
043	8/05	09°17'N	125°48'W	1843	20	80			80	12	0	0	Dark	Before & during BD
044	8/06	08°54'N	125°50'W	0816	17	400			400	6	1	2	17	Before BD
045	8/06	08°29'N	125°33'W	1351	54	250			250	5	0	1	1**	Before BD
046	8/09	12°22'N	130°16'W	0938	23	356	19		375	8	0	2	6	Before & during BD
047	8/09	12°22'N	130°30'W	1248	11	80			80	8	0	1	4**	Not tested
048	8/09	12°12'N	130°52'W	1631	11	600		400	1,000*	9	0	15	Rough	Before BD
049	8/13	12°44'N	127°27'W	0756	12	640	160		800	5	0	0	17	During BD
TOTAL					24 (average)	3,994	859	835	5,688	8 (average)	3	49‡	134	

Mortality - Set 039: One male neonate spotted died during backdown, entangled in 4 1/4" mesh at the bottom of the backdown channel. Another neonate spotter, sex unknown, died before backdown, cause unknown.

Mortality - Set 044: One female adult spotted died before backdown, entrapped in a small fold. This mortality could possibly be attributed to slow rolling of the net to increase research time.

*No crew estimate received - observer estimated ~85 animals captured on Set 34 and ~1000 animals captured on Set 48.

**Surface observations

† - 2 underwater cases recorded, 4 cases recorded from surface

a/All spotters

‡/44 Tons yellowfin, 5 tons skipjack

NOTE: The first 32 sets were made on Leg 1 of Cruise III

Table 2. Summary of 5-minute behavioral case observations

Type	Spotters	Spinners	Mixed Spot/Spin
Whole school	9	2	1
Male	28	12	-
Female	11	3	-
Sex unknown	9	1	-
Juvenile	19	5	-
Infants	4	0	-
Mother/infantpairs	22	8	-
TOTAL	102	31	1

b. Porpoise subgroups

The composition and behavior of numerous subgroups were recognized. Subgroups were initially identified by careful study of each animal associating with a focal animal; once types of subgroups had been identified, they could usually be recognized thereafter by characteristic behavioral patterns. Type and size of subgroups recognized on this cruise are given in Table 3. The methods of recognition for each subgroup are given in Appendix B.

c. Porpoise infant and adult behavioral interactions

Mother-infant and mother-infant pairs were observed in every set. There appeared to be no uniformity in the age of infants in either spotters or spinners; in both species, young of many ages were seen in every school. Neonates, identifiable by the presence of fetal folds and umbilical cords (which, in captive spinners, disappear in a week or so) were seen in one set only. It was observed that newborns do not need to swim to keep up with their mothers: the neonate rides on the mother's back, without moving its tail, apparently held in position by water pressure. This phenomena has been observed but not explained in captivity by K. Norris, R. Pener, and others. Photographs were taken.

Table 3. Types and sizes of porpoise subgroups observed, by species

Subgroup	Size of Group	Observed in	
		Spinners	Spotters
Solitary adult			
male	1	✓	✓
female	1	✓	✓
unknown	1	✓	✓
Solitary juvenile	1	✓	✓
Solitary infant	1		✓
Mother/infant pair	2	✓	✓
Courting pair	2	✓	✓
Other adult pair	2	✓	✓
Mother/baby/other adult triad	3	✓	✓
Juvenile subgroup	3-5	✓	✓
Young adult subgroup	3-20+	✓	✓
Mother/young subgroup	4-10	✓	✓
Senior male squad	3-8	✓	✓

Focal animal studies were made on 11 spotter mother-infant pairs and four spinner mother-infant pairs. Many other field observations were also made of mother-infant interactions.

d. Conditioned behavior

A number of responses thought to be learned behavior were observed. These included evasive techniques used during the chase, adaptive behavior in the net, and behavior exhibited before, during, and after backdown (a full discussion will be presented in Pryor's final report). Successful evasion during the chase, for example, by crossing the ship's bow to the right or by going under a speedboat, was often followed by conspicuous free-running individual leaps resembling those exhibited by most schools after the back-down release, Other indications of previous experience and learned behavior included running from the ship before speedboat pursuit began, running into rain squalls, "hiding" by rafting in the water during the chase, and ceasing to flee or to search for a way out of the set long before the net was fully deployed.

Observations were to be made throughout the duration of several sets to document changes that might occur over time in the sets. The number of case observations collected in each phase of the set is given in Table 4.

Table 4. Numbers of 5-minute behavioral case observations made by phase of set

Phase of Set	# of 5-minute Case Observations	
	Focal Animals	Whole School
Pre-chase	--	--
Chase	--	1
Setting & Pursing	42	5
Rolling Net	77	5
Backdown	3	1
Post backdown	--	--
TOTAL	122	12

Aside from the behavior and crowding that occur just before backdown, the behavior of the animals was relatively constant throughout the set, from the time of encirclement until just prior to release. For example, the percentage of animals rafting at the beginning of the set usually appeared to be similar to the percentage rafting at the end of the set. Far more difference was seen from set to set than within individual sets. Schools differed as to levels and sorts of activity; if courting behavior, for example, was occurring in a school, it would be wide-spread. Time of day also appeared to affect overall school behavior; for example, spotter schools were calmer, and social interactions, such as play, were more frequent in morning sets; evening sets were sometimes marked by a reduction in social interactions, both aggressive and affiliative, and by "impatience" or high levels of excitation just prior to release. During backdown, and just prior to it, subgroupings are difficult to discern due to crowding of the animals; however, focal animal sample data as well field observations indicate that subgroup members are still in close contact with each other. The impression of confusion is more apparent than real.

e. Longer-term observations

No attempts were made to hold the net open with speedboats in order to prolong observation time, as it was found that bringing the net aboard slowly, over a period of about an hour, afforded as long an observation period as the investigators could handle physically. Focal animal cases could be taken for about that length of time, but fatigue factors disrupted concentration at the end of such a period. Longer observation periods were not practicable, and the last ten minutes or so before backdown were often devoted to general observations, attempts to count the school, and photography.

f. Observations from outside the backdown area, and post-backdown

One set was observed from beyond the backdown channel, and several sets were observed from near the apex of the backdown area. For safety reasons, the investigators were prohibited from making underwater observations during backdown or outside the backdown area and from tying up directly at the apex. This limited the backdown observations to the surface. Following a school after release was not practicable with the available transportation and was not attempted.

2. General observations of porpoise schools during the set sequence[1]

Whole-school behavior during a set was analyzed by relating it to the set phases. The average time spent from sighting the birds or porpoise until end of set was 189 minutes, ranging from 135 to 264 minutes. The ranges and average time for each phase of the set are presented in Table 5. Surface behavioral observations were made on all 17 sets, 10 aborted chases and 13 schools of porpoise that were not chased.

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[1] Vergne

Table 5. Range of time and average time for each phase of the set

Phase of Set	Average Time (min)	Range of Time (min)
Pre-chase	35	10-69
Chase	25	9-66
Pursing	32	29-37
Rolling	30	25-46
Backdown	8	5-14
Post-backdown	59	32-118
TOTAL	189	135-264

a. Pre-chase

When the porpoise schools were first sighted, 16 were classified as traveling, 19 were classified as cruising slowly, and 5 were classified as milling in one general area. The traveling schools were observed moving in one of three types of formations. In the first of these traveling-school formations, groups composed of two or more animals were spread out over a large area (Figure 2). Each group moved back and forth within the general confines of the herd; however, the entire school moved in the same direction. Most of the porpoise were below the surface; however, members of a group surfaced in unison periodically to breath. Eight schools were observed in this formation. In the second formation,the porpoise swam in a single large wedge-shaped group with individual porpoise following each other head to tail (Figure 3). Most schools in this formation were moving at a good pace (an estimated 4 knots) with the individuals "porpoising" just above the water. Six schools were seen in this formation.

In the third formation, the porpoise moved in single groups with a long semi-crescent line. Individuals "porpoised" slowly on the surface front (Figure 4). It appeared that the porpoise were concentrated in the center of the line. Two schools were seen in this formation.

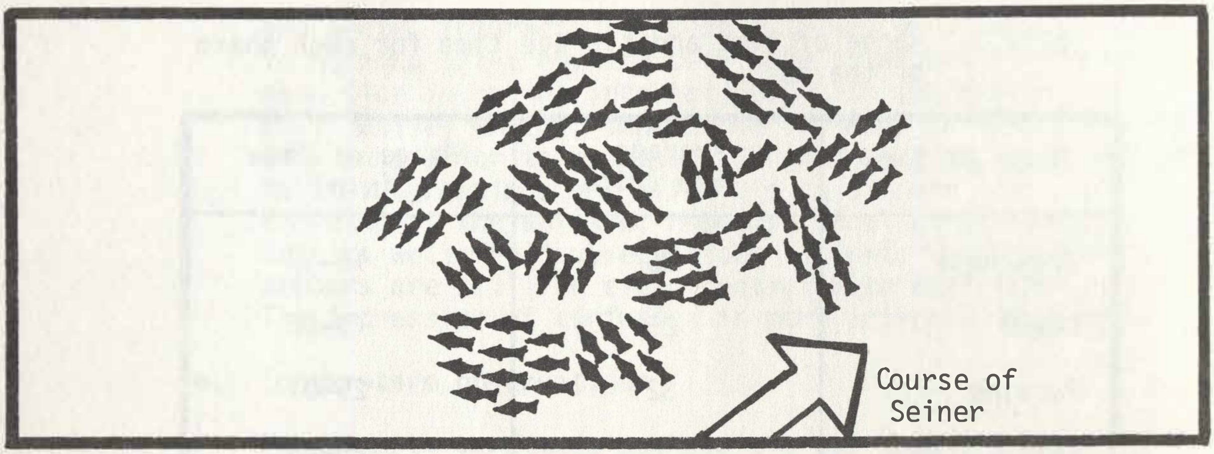

Figure 2. Formation of loosely aggregated traveling school (area covers about 1 square mile)

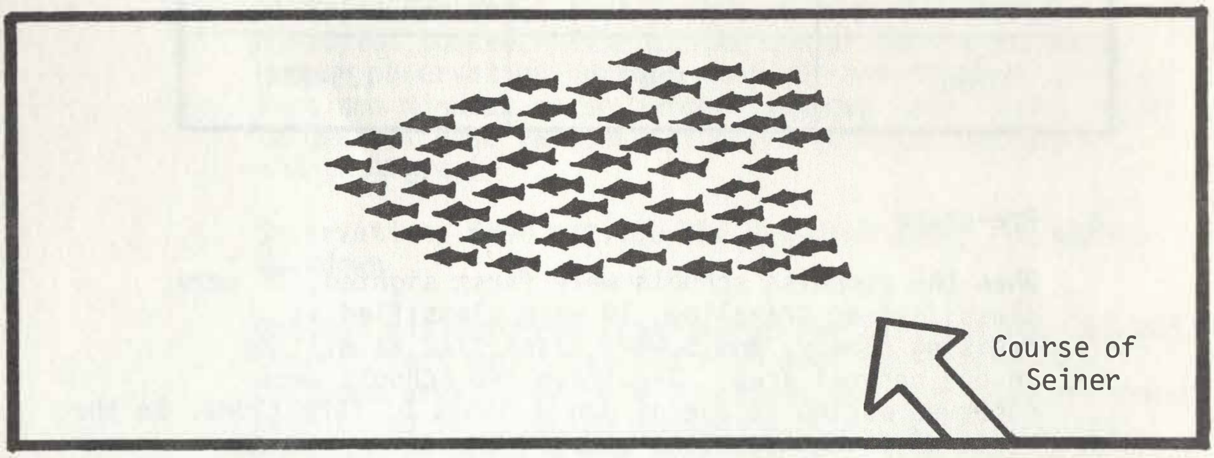

Figure 3. Formation of traveling school in wedge-shape (area covers about 3000 square yards)

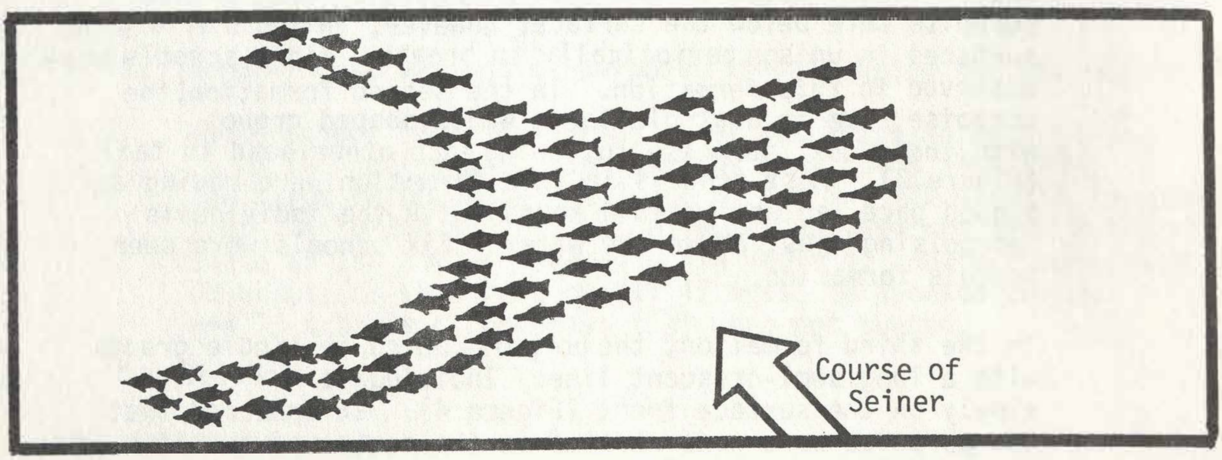

Figure 4. Formation of traveling school with crescent front (area covers about 4000 square yards)

Cruising schools assumed no definite formation, but all porpoise moved slowly in the same direction. Groups of porpoise would join larger groups, then break up, only to form again, while the entire porpoise mass moved about two knots in one general direction.

Milling schools displayed very little surface activity. These schools were presumably resting or feeding. They appeared to be spread out in a loose circle with an area of greater activity in the center. Surface behavior was restricted to porpoise breaking the surface while breathing. Schools that were presumed to be feeding usually had groups of porpoise moving around in erratic patterns. Surface splashes and fins breaking the water were common. Birds were usually flying overhead and feeding in the areas around the porpoise.

When the porpoise reacted to the approaching vessel (usually at an estimated 3 to 4 miles away), there was a noticeable increase in activity. Schools that appeared to be traveling increased swimming speed and either broke up into smaller groups or came together in a tight pod. Within milling and feeding schools, the increased activity and aerial display seemed to occur first on the periphery of the school. If the porpoise schools were approached to within three miles and the chase started, the porpoise would either begin rafting (2 schools) or would start running (25 schools).

b. Chase

The two schools that started to raft remained low in the water and held aerial display down to a few tail slaps or fins breaking the surface. They did not appear to respond to the speedboats.

The 25 schools which ran responded several ways to the speedboats. The school would bunch up, and the porpoise would run with long leaps. In a mixed spotter and spinner school, the spinners appeared to be clustered around the spotters, seemed to leap higher than the spotters, and would spin at various times during the chase. As the chase progressed, the school's running speed would vary in response to speedboat pressure. At times the porpoise barely appeared to move, and at other times they appeared to be running at full speed in long leaps (no speed estimate could be made). When the net skiff was released, the porpoise in the set would slow down and start milling approximately 100 yards away from the wake of the seiner.

The porpoise that evaded capture during a chase appeared to recognize when they were no longer chased. Individuals took off in a manner similar to that followed in a post-backdown release run, swimming a short distance underwater, coming up for air, swimming underwater for a distance of 15 to 20 feet, then taking off, leaping and splashing in a much more conspicuous manner than during the chase. They then slowed down when less than a mile away from the vessel. In one set, some were observed to raft a few hundred yards off the ship's beam.

c. Setting and pursing

When the porpoise were first encircled by the net, three speedboats usually circled off the stern of the vessel to prevent the porpoise from escaping from the seine while the towline was being retrieved. At this time of the set, the porpoise were generally swimming restlessly directly abeam the seiner, about two-thirds of the distance from the vessel to the corkline.

During this part of the set, there was a great deal of social interaction, such as stroking, swimming together, and playing. Groups of porpoise or indivuals swam around milling or rafting. There was much whistling, and curtains of bubbles rose from subsurface or diving animals. Underwater group structure did not appear to be static, but rather that of individual subgroups moving around a loose nucleus of older animals. For instance, female and offspring pairs would form loose units with similar pairs. These pairs would be joined by a single male or groups of males. Some of the pairs would leave, joining other groups, and the males would leave to be replaced by other pairs and so on, the whole school forming a dynamic unit, which is constantly changing.

There was a slight surge in activity by the school manifested by increased swimming speed and surface aerial displays when the rings were put on the stripper. The effect was that of a momentary shift in the position of the whole school. The movement was probably because of the noise created when the rings were put on the ring stripper. By the time the crew started rolling the net, behavior returned to the previous modes.

d. Rolling

During the initial stages of net rolling, the behavior of individuals and schools was comparable to behavior during the latter parts of pursing. As net rolling continued, there were no apparent changes in individual or group behavior, but the entire school shifted slowly toward the backdown area. As the surface area of the net was reduced, the activity level in the school increased. The incidence of whistling and chuffing*appeared to be more frequent, with porpoise surfacing to breathe more often as they were stressed and crowded in tighter groups. School cohesiveness was still apparent underwater, but could not be discerned from surface observations. Group structure was maintained, and the groups observed earlier in the set were still distinguishable. Inter-group distances appeared to be reduced. By tie-down, the porpoise were usually in a tight ball about 15 yards from the backdown apex. Interactions such as tooth raking, striking, stroking, and so forth were less frequent, and porpoise concentrated on keeping away from the net. Porpoise were very adept at keeping away from the net, but once they came in contact with it, they appeared to cope with the situation in only two ways. They became passive and slowly sank,or they struggled until they freed themselves or became entangled.

e. Backing down

Behavior modes after tie-down remained constant until a few animals were released over the corks. Then behavior in the net changed drastically because (1) the net was being pulled from under the porpoise by the backing-down process and (2) some porpoise were actively leaving the net by going over the sunken corks around the apex area. Individual porpoise, or groups of porpoise, were backed out pell mell over the corks and did not immediately realize that they had been released, while other individuals or groups swam over the corks apparently seeking release actively.

f. Post-backdown

Once the porpoise realized they were free of the net, they took off in a very distinctive post-release run. They came to the surface, breathed once, swam 15 to 20 feet underwater, then leaped in the air, landing with a splash. They continued this leaping for 1 or 2 miles before they slowed down.

g. Composite behavioral sequence for a typical set

Among the schools observed, there appeared to be a definite continuity and similarity in-school behavior from the pre-chase stages to post-backdown release. A composite behavioral sequence for a typical set on this cruise follows.

During the approach by the seiner, the porpoise schools were either traveling (generally heading in the same direction at a speed of 3 to 4 knots), swimming slowly (about a knot), or milling. Surface activity was low,and there was very

*Chuffing is defined in Appendix A.

little aerial display. As the vessel approached, the porpoise and the speedboats were lowered, the activity level increased. Aerial display, such as leaps and spins, and swimming rate increased until the school was running and porpoise were leaping freely out of the water. The school was then herded by the speedboats to intersect the wake of the main vessel. By this time, the porpoise were usually bunched and swimming slower than at the onset of the chase. When the net skiff was released, the porpoise were milling, approximately 100 yards away from the seiner and its wake. There was much aerial display at this time, and the school moved back and forth restlessly. This activity level remained constant until the stern end of the net was at the seiner and the speedboats stopped circling between the skiff and the stern side of the seiner. Activity levels then decreased and the porpoise were observed to adopt one of three discrete school patterns. These patterns were maintained until the start of backdown.

- About two-thirds of the school rafted at the surface with the remaining animals distributed in four or five subsurface layers (Figure 5). This pattern was observed in 12 schools.
- The school milled about with less than one-fifth of the porpoise on the surface and the rest distributed in a rotating column about 100 feet deep (Figure 6). This pattern was observed in 3 schools.
- One-fourth of the animals rafted on the surface while the rest of the school swam or milled in a tight group about 20 feet below the surface animals (Figure 7). This pattern was observed in 1 school.

(Note: The figures are not intended to provide actual numbers or estimates of animals in the school, or in each layer or subgroup.)

Groups of porpoises moving up and down through these layers were observed displaying typical social behavior such as whistling, echo-locating, and stroking. Subgroups comprised of mother-infant pairs, juveniles, small groups, and adult males were observed at all levels.

As the rings were placed on the ring stripper, there was a slight increase in activity manifested by short bursts of speed and a general movement of the rafting groups. As the net was rolled, the school edged toward the backdown area while maintaining the school structure. As the area

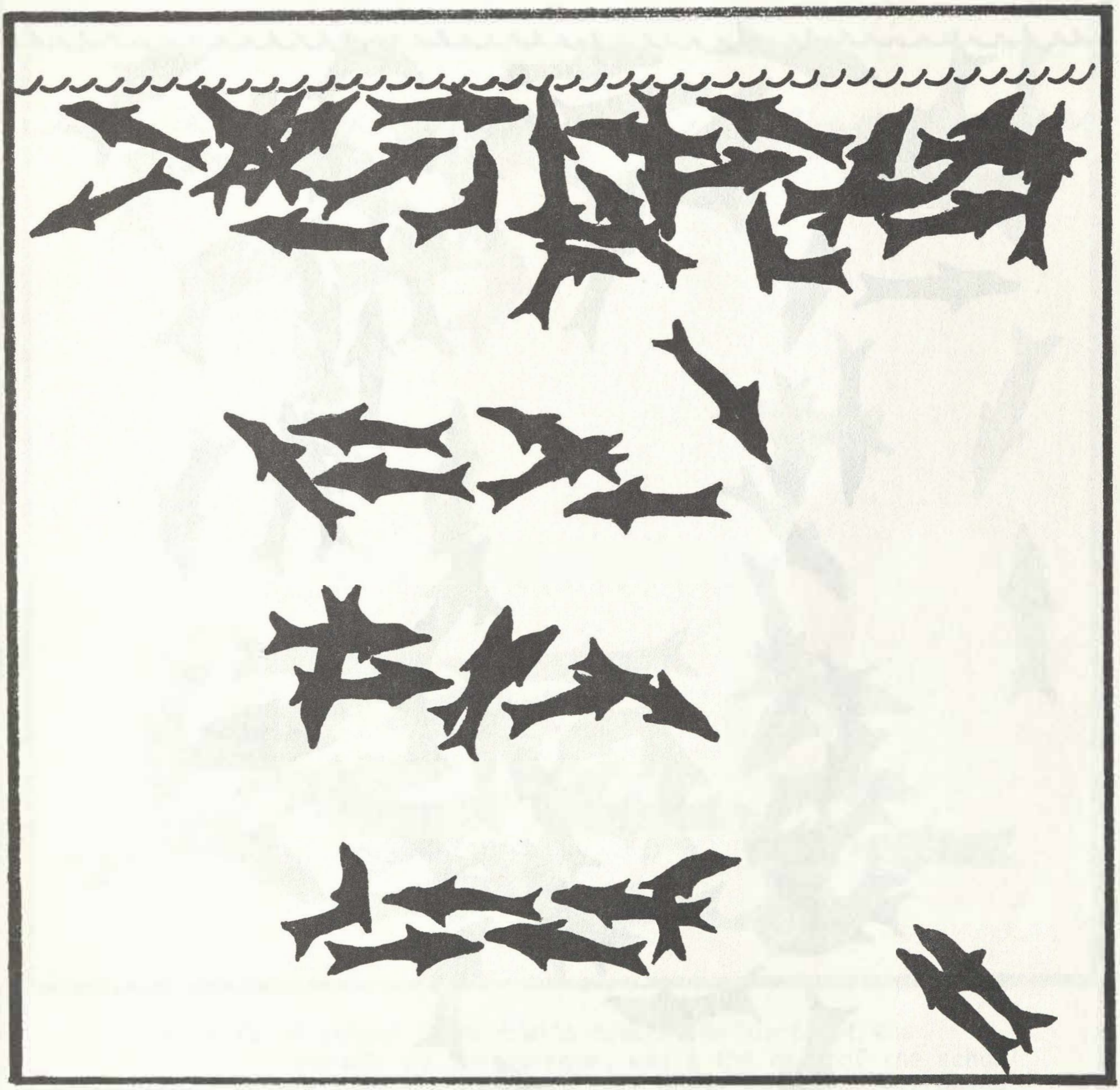

Figure 5. A school pattern with about two-thirds of the porpoise on the surface and the remaining animals distributed in several subsurface layers (surface area occupied was estimated at 40 by 60 feet, depth was over 100 feet).

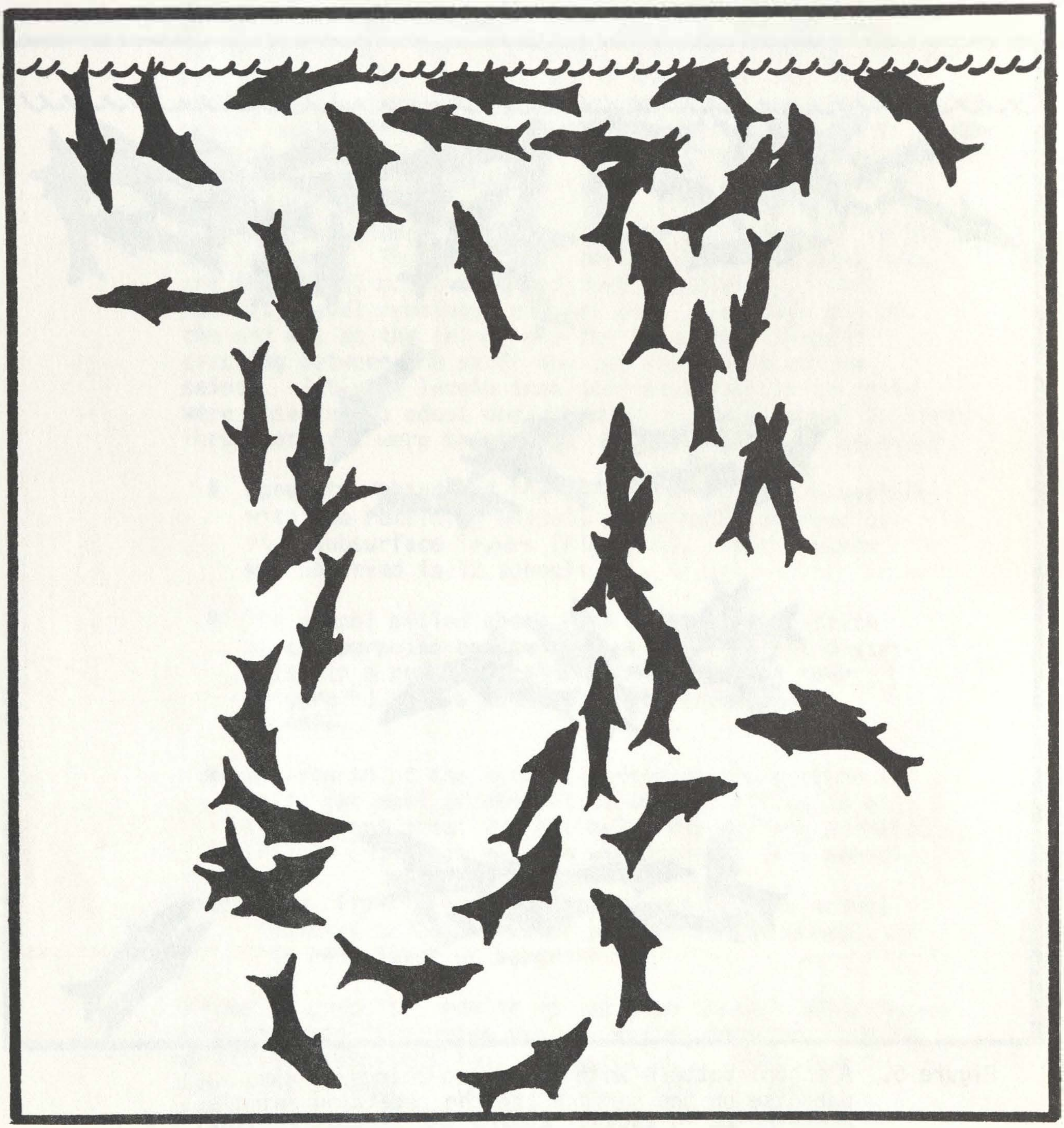

Figure 6. A school pattern with less than one-fifth of the school at the surface and the rest distributed in a rotating column estimated at 100 feet deep (surface area occupied was estimated at 25 by 50 feet).

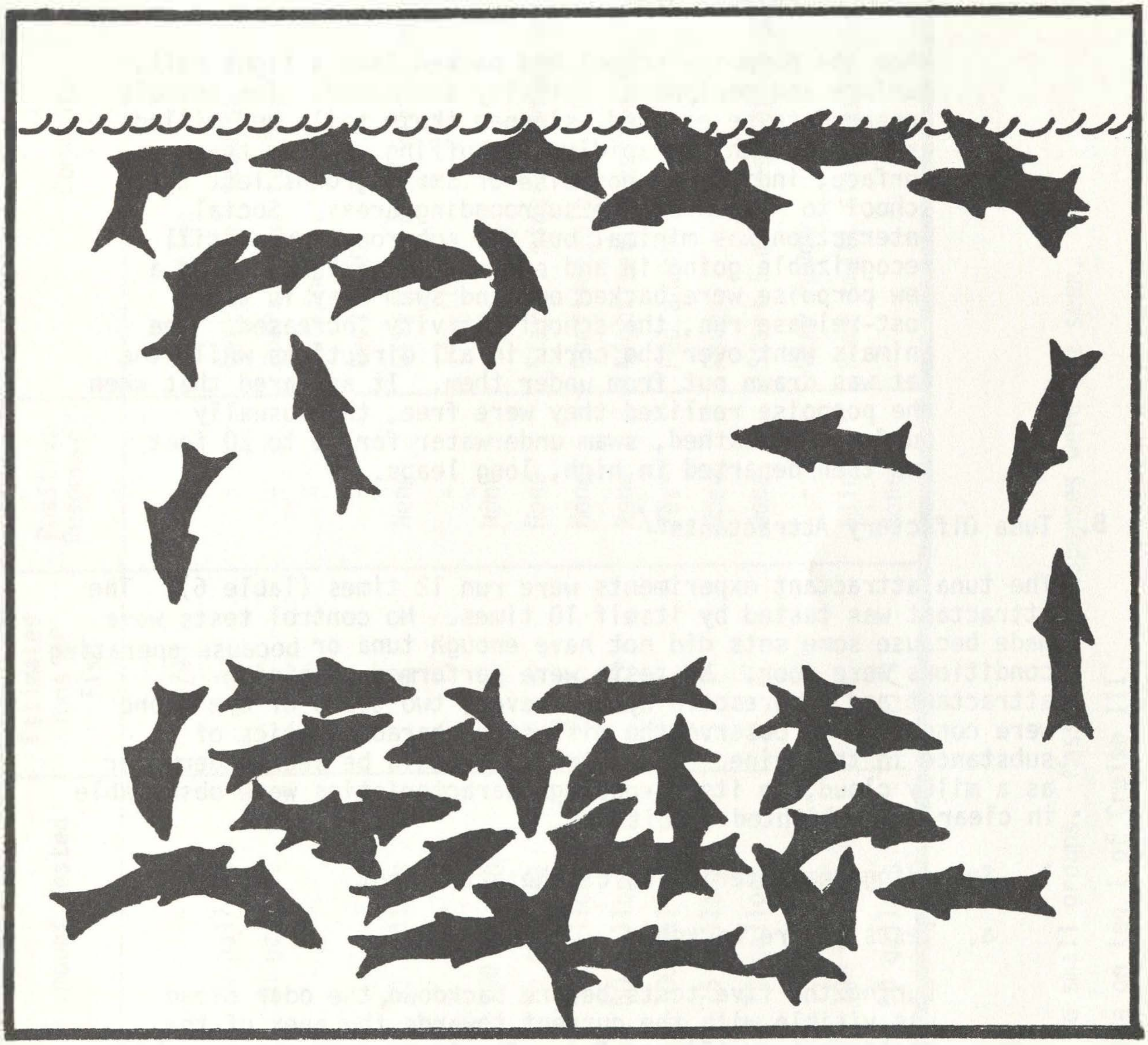

Figure 7. A school pattern with about one-fourth of the animals at the surface, while the rest of the school swam or milled in a tight group about 20 feet below the surface animals (surface area occupied was estimated at 15 by 20 feet).

decreased, the inter-group and inter-animal distance decreased until the school formed a tight ball in the backdown channel area.

When the porpoise school had packed into a tight ball, surface and peripheral activity increased. The animals appeared to be excited, slapped their tails and milled around, breathing rapidly or chuffing. Below the surface, individual porpoise or small groups left the school to "explore" the surrounding areas. Social interaction was minimal, but the subgroups were still recognizable going in and out of the core unit. As a few porpoise were backed out and swam away in their post-release run, the school activity increased. The animals went over the corks in all directions while the net was drawn out from under them. It appeared that when the porpoise realized they were free, they usually surfaced, breathed, swam underwater for 15 to 20 feet and then departed in high, long leaps.

B. Tuna Olfactory Attractants[1/]

The tuna attractant experiments were run 12 times (Table 6). The attractant was tested by itself 10 times. No control tests were made because some sets did not have enough tuna or because operating conditions were poor. No tests were performed combining attractant and fluorescein dye; however, two tests of dye alone were conducted to observe the diffusion characteristics of a substance in the seine. The attractant could be seen underwater as a milky cloud, so its spreading characteristics were observable in clear, well lighted conditions.

1. Spreading characteristics of the attractant

a. Tests before backdown

During the five tests before backdown, the odor cloud was visible with the current towards the apex of the backdown area (Figure 8). The tests were started about 5 minutes before backdown at the time the backdown channel generally is starting to form. The odor cloud was observed moving very slowly downcurrent towards the apex during three of these tests. No estimate was made of the speed in the other two sets.

b. Tests before and during backdown

One of the three tests made both before and during backdown was during a night set in which the hose was placed over the side into the net. Observations made from the seiner precluded determination of the spreading characteristics of the attractant.

[1/] Ikehara

Table 6. Summary of tuna olfactory attractant sets

Set #	Phase of Set	Amount Tested	Estimated Tons of Fish	Positive Response*	Comments
33	-	-	(1/4)	-	Orientation set
34	Dye before BD	20 gallons	3	-	Operational testing
35	Dye before BD	20 gallons	1	-	Operational testing
36	-	-	2	-	Declined
37	-	-	0	-	Declined
38	Before BD	50 gallons	5	None	Difficult observation conditions
39	-	-	1	-	Too rough
40	Before BD	100 gallons	6	None	
41	Before and during BD	75 gallons	9	None	Start 5 minutes before BD
42	During BD	50 gallons	2	None	Questionable
43	Before and during BD	50 gallons	(1/2)	None	Night set, questionable
44	Before BD	100 gallons	2	Yes**	Fed anchovies
45	Before BD	75 gallons	1	None	Rough
46	Before and during BD	75 gallons	2	None	Start 5 minutes before BD
47	-	-	1	-	Very rough
48	Before BD	100 gallons	15	Slight**	Some small fish responded
49	During BD	50 gallons	(1/4)	None	

BD: backdown

*Response subjectively estimated

**Referring to individual fish or to small groups. Mass school responses were not seen.

NOTE: The first 32 sets were made on Leg I of Cruise III

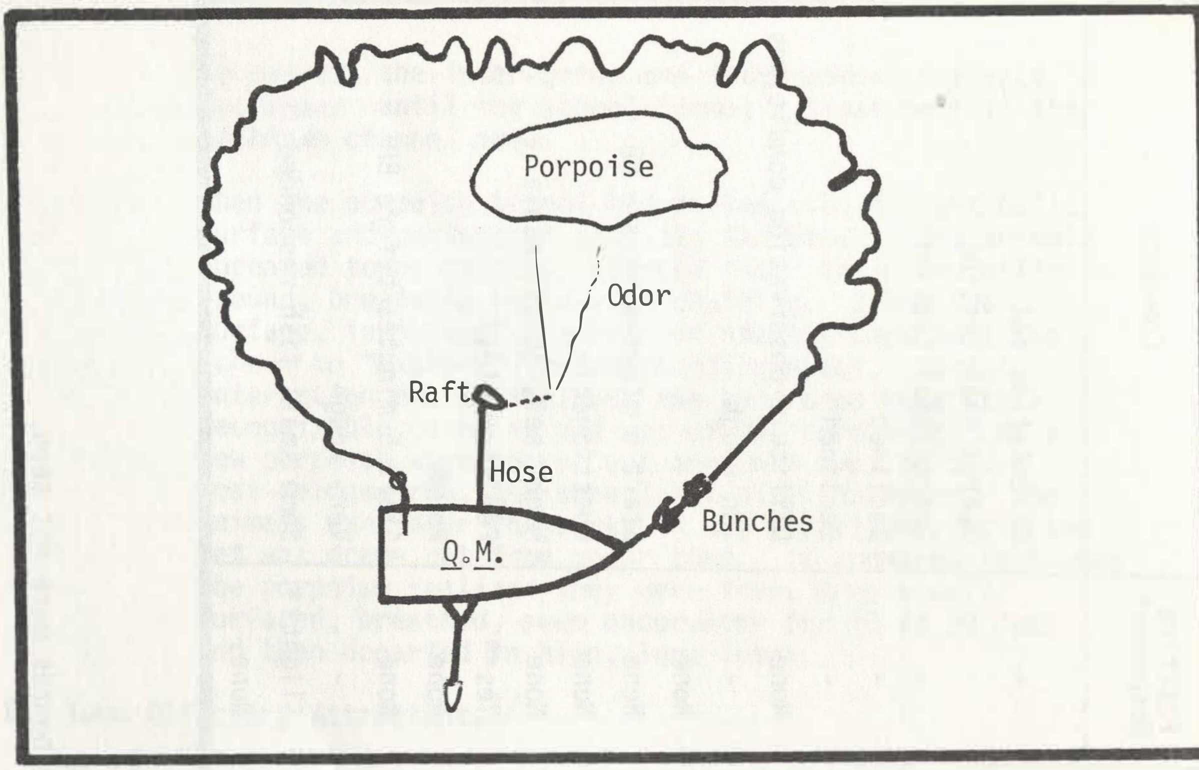

Figure 8. Net configuration during tuna attractant tests before backdown. (There were two observers in the raft, one paddling and one observing over the side. The hose hung from a float about 3 yards from the raft. The net was being rolled slowly after rings were up.)

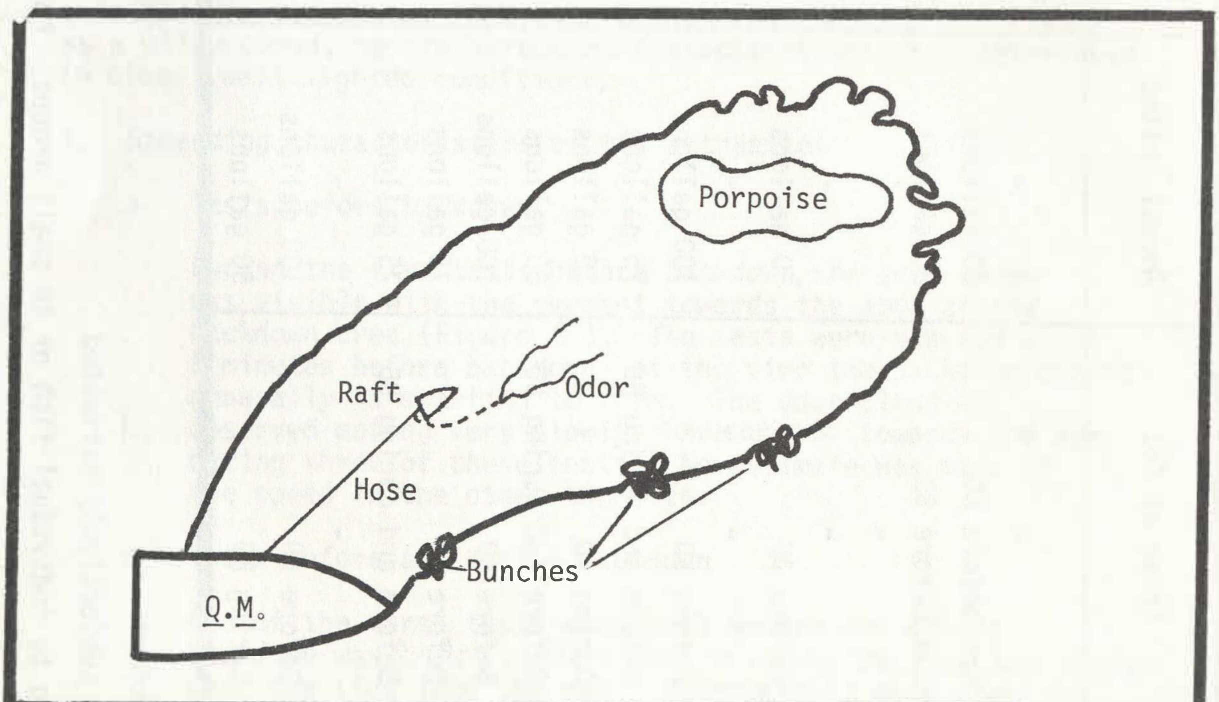

Figure 9. Net configuration during the tuna attractant tests before and during backdown.

On another set, the odor cloud was seen drifting towards the porpoise and fish during the testing (Figure 9). During the third set, because there was little current, the odor cloud rose around the hose end before backdown, and drifted out toward the apex during backdown.

c. Tests during backdown

Two tests were conducted during backdown. During one test, the odor cloud moved up the backdown channel towards the apex (Figure 10). During the other test, because of rough weather, about 10 fathoms of hose were placed over the side into the net. Observations were made from the seiner, and the spreading action could not be determined.

d. Dye tests

The dye tests were made before backdown. During the first test, the dye moved towards the porpoise but went out the bottom of the net because the hose was on the floor. During the second dye test, the hose was suspended with a float. The dye moved with the current out the bow side of the net near the bunches, never approaching the porpoise-tuna aggregation.

2. Tuna response to the attractant

Based on behavioral studies in captivity, yellowfin tuna indicate a positive response to odor when they display one or more of the following characteristics:

- Feeding coloration, i.e., the display of feeding bars when the tuna are in vicinity of the odor cloud;
- Dorsal fin erections, pectoral fin spreads, gaping, or jaw snapping;
- A sudden increase or decrease in swimming speed, marked by a rapid increase in tailbeat rate or a sudden cessation of tailbeating for a short period;
- An increased frequency of turning or a decrease in tuna size;
- Gradient-searching behavior, indicated by a slow-down in speed and the exaggerated side-to-side movements of a typical searching action down stream of the odor source, with the tuna generally headed up current;
- A general increase in activity, apparent arousal or an orientation that cannot be attributed to other causes;

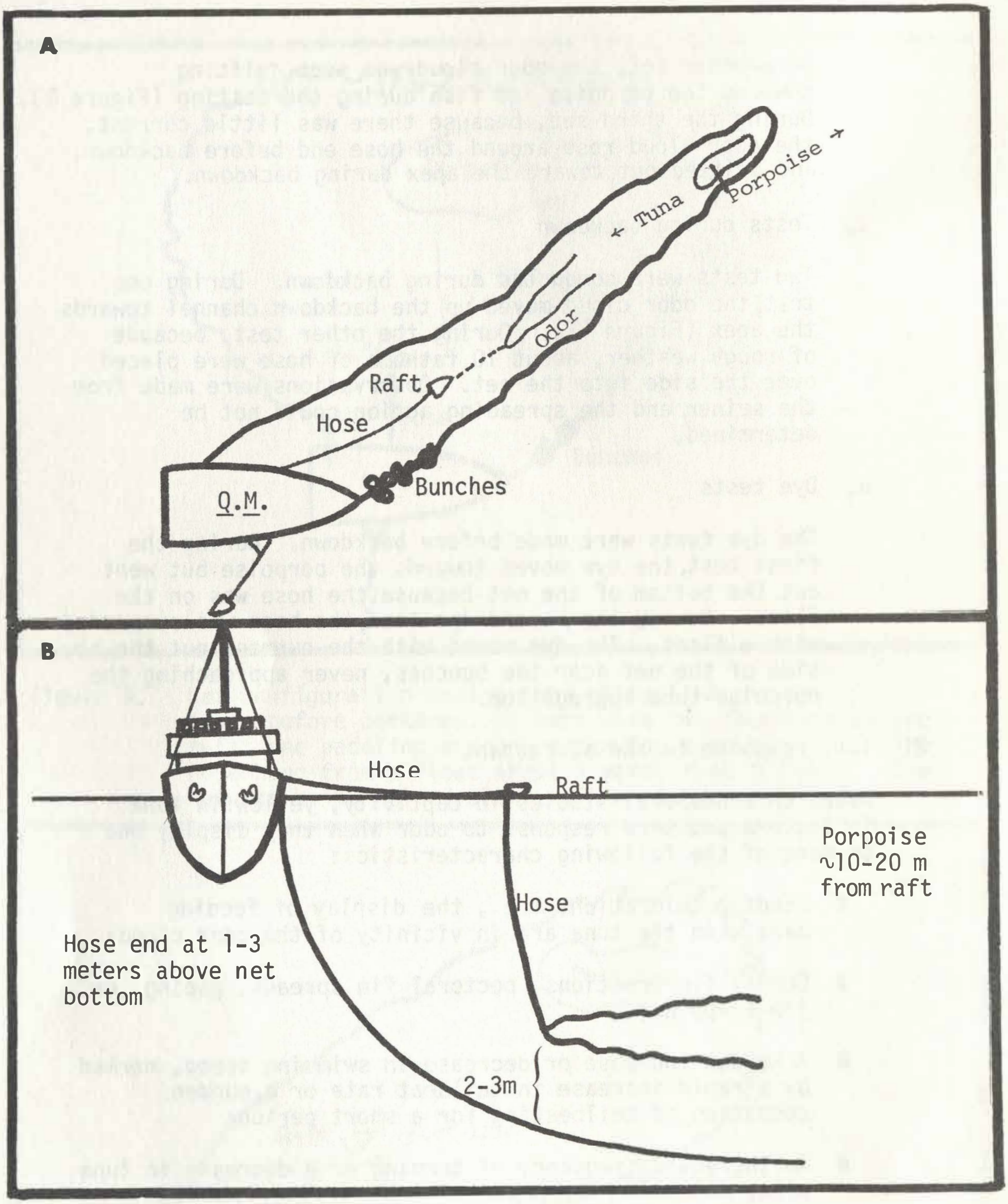

Figure 10. Net configuration during tuna attractant tests during backdown. (A: aerial view B: side view)

- A breakdown in uniform school swimming pattern resulting in highly individual swimming patterns and irregular swimming compared to normal behavior;
- An attraction to the odor cloud indicated by a lengthy stay and by a display of the behaviors mentioned above, either while in the cloud or after passing through it.

The appearance of any of these behaviors presumably indicates a response. Responses tend to be variable, and many behaviors overlap; however, after training and experience they are easily recognized. The degree of response is judged by the intensity of behavior and the pervasiveness of the response in the school.

The attractant was tested in 10 sets. A response was observed in only two sets--Sets 44 and 48. The response in Set 48 was minor. A few small yellowfin showed some excitement, but no response was seen from the school. No response was observed from a shark swimming deep with the tuna.

Positive responses to the attractant were seen only in Set 44 when the attractant was tested before backdown. About 7 minutes before backdown started, the tuna approached the end of the hose to investigate it. They returned five more times in the next 8 minutes. Each time they displayed a positive response. Feeding bars and dorsal fin erections were seen in some of the fish as well as an increase in swimming speed and a tendency to circle downstream from the hose. A few tuna exhibited some gradient following behavior. However, the school did not stay near the hose for long periods and eventually returned to the deep end of the net or the vicinity of the porpoise.

During backdown on Set 44, frozen anchovies were thrown upstream to the school. The smaller yellowfin came up first to investigate and eat and were followed by the larger tuna. There was little hesitation in taking the dead bait, although captive fish must be trained to take dead food. Skipjack tuna were seen chasing and feeding on flying fish before backdown on one set and, on another, were observed striking at an apple core.

3. Effectiveness in breaking the porpoise/tuna bond

Some yellowfin were attracted to the odor cloud in two sets (44 and 48) but usually stayed for only short periods of time before moving back to the porpoise area. During Set 44, 2 tons of yellowfin, the total catch in that set, milled around the end of the hose several times for up to a minute at a time and showed feeding bars and dorsal fin erections. In Set 48, about a half ton stayed around the end of the hose for about 10 seconds. On all occasions, the fish returned to the porpoise aggregation. During the other eight tests, the tuna usually remained deep near the porpoise and showed only common movement patterns within the purse seine.

4. Behavior of tuna associated with porpoise[1]

While the net was still deep (prior to backdown), the tuna remained close to the porpoise. They were usually below and generally slightly to the side of the porpoise and swam in a circular or figure-eight pattern which took them about 50 feet on either side of the porpoise school. Porpoise showed a very definite avoidance reaction to yellowfin or skipjack when the tuna approached closer than 10 to 15 feet. The tuna generally swam 15 or more feet deeper than the deepest porpoise, although at times they were seen higher than some porpoise but always on the periphery of the porpoise school. Skipjack usually swam deeper than the larger (over 40 pounds) yellowfin.

The tuna were never observed surfacing among the porpoise. However, they would surface on one side of the porpoise school, dive down under the school and resurface on the other side (Figure 11). Smaller (7 to 10 pounds) yellowfin and all skipjack tuna appeared to swim around the net without any particular pattern other than their periodical return to the porpoise (Figure 12).

All tuna showed interest in the rafts in the net. The yellowfin (over 40 pounds) would come straight up from the depth of the net and stop about 20 feet below the raft and a little to the side. They remained motionless for a few seconds, then resumed swimming, at times circling around the raft at 30 feet or more and at a depth of about 20 feet. In one set, immediately after rings up (Set 34), the tuna school followed as the raft moved back to the corkline (150+ feet). They stayed a few minutes, then followed the raft as it went back to the porpoise and resumed swimming beneath the porpoise school.

The tuna also showed an interest in other objects in the net. During Set 48, the tuna followed a 4-foot shark (sp. unknown) from immediately after the purse rings were up until the middle of backdown. During another set, the tuna followed a 6-foot manta ray (*Manta hamiltoni*) just prior to and during backdown. However, they did not appear to pay attention to it earlier in the set.

When the depth of the net in the backdown channel was less than 25 feet, tuna swam up and down the channel seemingly unaware of either the porpoise or raft, concentrating on staying away from the net and on looking for an escape.

[1] Vergne

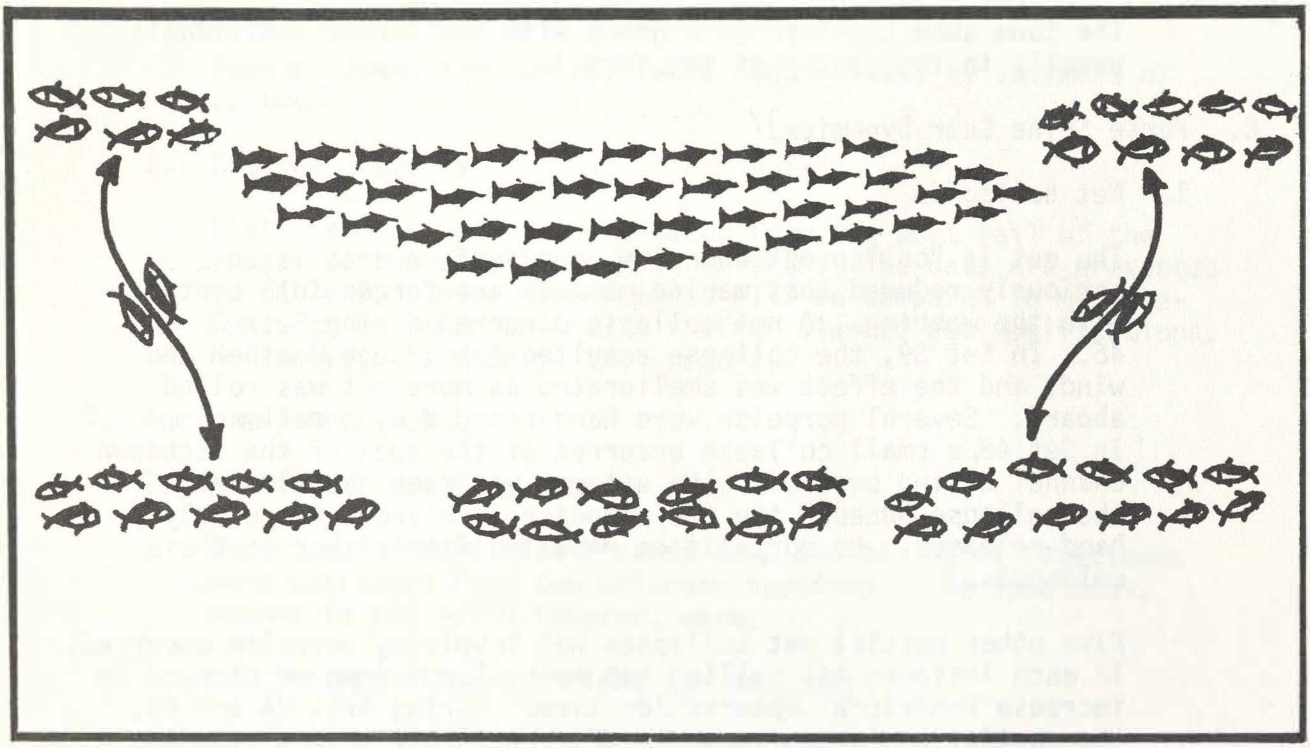

Figure 11. Side view of the movement of the large yellowfin tuna in relation to the porpoise school

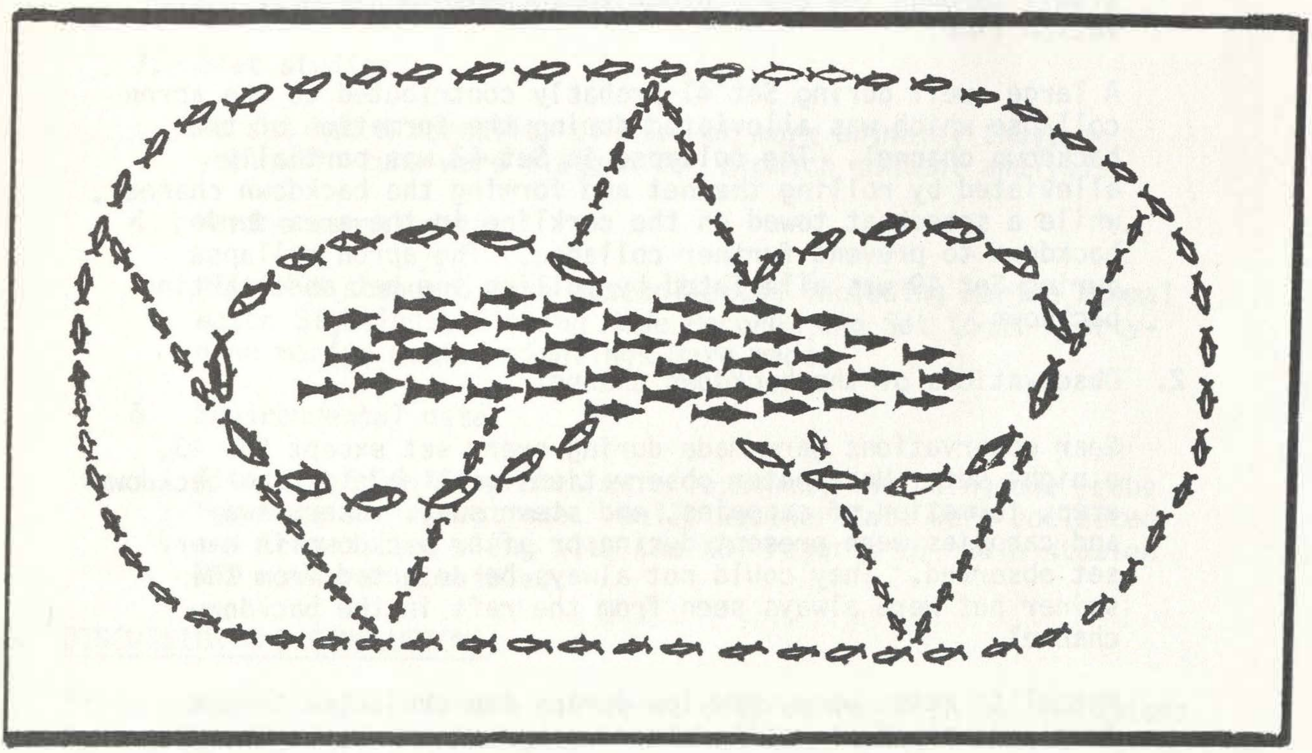

Figure 12. Overhead view of the movement of the skipjack and yellowfin in relation to the porpoise school

small YF and SJ   large YF   porpoise

The tuna swam together as a group with the larger individuals usually in the center of the school.

C. Purse Seine Gear Dynamics[1/]

1. Net collapses

The net is "collapsed" when its open surface area is so seriously reduced that marine mammals are forced into contact with the webbing. A net collapse occurred during Sets 39 and 46. In Set 39, the collapse resulted from rough weather and wind, and the effect was ameliorated as more net was rolled aboard. Several porpoise were hand-rescued by a raftman. In Set 46, a small collapse occurred at the apex of the backdown channel during backdown. No attempt was made to alleviate the collapse because the two porpoise involved were quickly hand released. No mortalities resulted from either of these collapses.

Five other partial net collapses not involving porpoise occurred. In each instance net rolling had been slowed down or stopped to increase behavioral observation time. During Sets 34 and 40, the partial collapses occurred after net rolling was stopped and were alleviated when net rolling resumed. The net collapse in Set 40 involved the apron, and other apron collapses in Sets 41, 42, and 49 all occurred because the net was rolled slowly through the power block to increase behavioral observation time.

A large swell during Set 41 probably contributed to the apron collapse which was alleviated during the formation of the backdown channel. The collapse in Set 42 was partially alleviated by rolling the net and forming the backdown channel, while a speedboat towed on the corkline in the area during backdown to prevent further collapse. The apron collapse during Set 49 was alleviated by rolling the net and starting backdown.

2. Observations of the backdown channel

Gear observations were made during every set except Set 43, a night set. Underwater observations were made of the backdown area, formation of canopies, and stern sway. Stern sway and canopies were present during or after backdown in every set observed. They could not always be detected from the seiner but were always seen from the raft in the backdown channel.

Mortality rates were very low during the cruise, although large groups of porpoise entered canopies and become temporarily trapped. Most of these were released by rolling the net or

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[1/] Bratten

backing down, and the rest were hand rescued by swimmers or raftmen.

3. Net measurements

Distance measurements were taken from the port rail of the vessel to the corkline during 12 sets. The data are presented in Table 7. These measurements will be compared to measurements to be taken on Cruise V after planned net modifications. No analysis is made in this report.

D. Ancillary Research 1/

1. Biological and life history data

The standard NMFS life history data and biological specimens were collected from two offshore spotters. The specimens, stored in the -60°C freezer, were:

a. One eyeball and a right jaw section;

b. Tissue samples from the heart, lung, liver, kidney, spleen, skeletal muscle, brain, melon, and adrenal glands; and

c. Post-mortem blood samples.

3. Diet studies

No set had a mortality of five or more animals; thus, no yellowfin tuna were flagged for stomach content analysis.

4. Marine mammal data

All NMFS standard data was collected including Marine Mammal Watch Sightings, Fishing Mode Record, and Set Logs. Forty-nine marine mammal sightings were made.

5. Environmental data

A total of 36 XBT probes were launched, including one probe for each set except one. Daily weather data were collected and transmitted along with the XBT reports to radio station WWD whenever possible.

VI. DISCUSSION AND CONCLUSIONS

Three porpoise, all offshore spotters, died during fishing operations. During Set 39, two neonatal porpoise died, one before backdown for unknown reasons and the other after becoming snout-entangled in 4¼-inch mesh at the bottom of the backdown channel. The third mortality

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1/ Bratten

Table 7. Net measurements (distances in meters from port rail amidship)

Leg II Set #	Ortza in			One-half pursed			Rings up			Start backdown to apex	End backdown to apex
	1/4 net	1/2 net	3/4 net	1/4 net	1/2 net	3/4 net	1/4 net	1/2 net	3/4 net		
033	-	-	-	-	-	-	-	-	-	-	-
034	-	-	-	-	-	-	-	-	-	-	-
035	135	155	175	130	120	160	95	73	103	-	-
036†	92	80	85	-	-	-	45	50	52	-	-
037	-	-	-	165	180	145	80	105	97	-	-
038	185	270	210	145	175	125	90	83	85	-	-
039	225	300	260	125	185	180	110	85	88	105	105
040	290	350	290	120	135	120	80	70	82	-	130
041	205	240	150	140	180	130	95	65	74	-	85†
042	215	220	240	180	120	113	100	68	80	-	-
043	-	-	-	-	-	-	-	-	-	-	-
044	270	260	190	140	145	145	92	80	88	105	-
045	-	-	-	-	-	-	-	-	-	-	-
046	270	260	150	150	160	135	100	100	92	100	-
047	280	-	190	135	118	103	65	95	78	95	128
048	280	-	175	-	175	130	85	76	90	-	-
049	-	-	-	-	-	-	-	-	-	-	-
Ranges and Averages for Leg II (number of measurements in parenthesis)											
LOW	92	80	85	120	118	103	45	50	52	95	85
HIGH	290	350	290	180	185	180	110	105	103	105	130
AVERAGE	222	237	192	143	154	135	86	79	84	101	112
	(11)	(9)	(11)	(10)	(11)	(11)	(12)	(12)	(12)	(4)	(4)

* - 'Ortza in' and '1/2 pursed' occurred at the same time.
† - Measurements made by other member of the scientific party
Second leg measurements made by Dave Bratten, NMFS

occurred in Set 44 when an adult female became entrapped prior to backdown in a fold beneath some bunched up corks near the backdown area. This area of the corkline became bunched up after net rolling had been stopped to increase research time.

Research carried out during the second leg of Cruise III demonstrated the feasibility of having researchers inexperienced in purse seining operations conduct tuna/porpoise research at sea. While the investigators had background primarily in captive-animal studies, they quickly adapted to at-sea research once they became familiar with fishing operations and necessary safety precautions. After several sets, coordinating the attractant and behavior studies into the time frame of the set became easier as the procedural technique for each study was refined. Both groups were flexible in relinquishing investigative time to allow the other to reach certain research plateaus. The attractant study fell slightly short of its goal in that the researchers could not test all samples because few sets had enough fish.

Research involving free-diving observations as performed by the behavior team can be hazardous, even when extensive safety precautions are taken. Although sharks captured with porpoise schools usually appear passive in the net, they are unpredictable and often are curious about floating objects such as rafts. They often remain out of view until well after pursing is completed and occasionally are not seen until brailing operations. Future research plans involving free-diving observations should include safety precautions.

A. Observations of Porpoise Behavior [1/]

Detailed discussion of porpoise behavioral observations made on this cruise necessarily await full data analysis. Nevertheless, some preliminary conclusions may be drawn.

It seemed clear that at least some animals in every school set on had previously experienced a set and had developed learned or adaptive responses to the fishing procedure. The porpoise repeatedly demonstrated this experience in their leaps. There is a difference between leaps made during the chase and leaps made during release. The leaps of the released-animal (free-running leaps) were also exhibited when they successfully evaded capture, suggesting that they have learned escape maneuvers and recognized their success.

Familiarity with the net is also shown by the occurrence of affiliative and other social interactions during a set, by avoidance of the net itself, by voluntarily crossing the corkline, and, perhaps, by the drifting of the school to the backdown area after rings-up.

In addition to concern about mortality as such, the scientific and environmental communities have postulated possibly less

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[1/] Pryor and Kang

obvious, but also serious, deleterious effects of the fishing on porpoise schools. For example, very high stress levels might in themselves affect porpoises over a long term. The long chases might cause the loss or abandonment of neonates which theoretically could not keep up the pace. Schools might be predated upon unevenly: if, for example, animals which escape are larger, stronger males, then mortality would occur at a higher rate among females and young. Finally, the fishing might disrupt the social structure of the school in a permanent and harmful way.

One of the findings was that apparent stress levels were lower than had been anticipated. Panic and shock, as indicated by known behavioral signals in these species in captivity (Appendix A), were not observed, and most schools were calm enough to carry on ordinary social interactions until backdown. While much more data may be needed to resolve questions of stress levels, the data gathered on this cruise suggests that, at least in experienced schools, acute stress is not a wide-spread phenomenon, but rather the opposite.

Brief observations of neonates suggest that the mother can and does "carry" the baby during rapid swimming, thus providing a method whereby neonates may travel with the school at any speed. The set in which two neonates were observed was made after a 12-minute high-speed chase. The ranges of infant age and behavior will be discussed in a subsequent report.

The identification of types of subgroups in the schools offers interesting evidence for continuity of social structure in the school, not only throughout the set but over longer periods. Major kinds of subgroups, such as mother/young groups, juvenile groups, and senior male squads, were seen in every set, whether there were as few as 20 or many hundreds captured.

Individuals were sometimes recognized as staying together throughout the set. Far from being a random aggregation, a porpoise school appears composed, at least in part, of individuals that recognize each other and associate in structured ways. Since all recognized types of subgroups were seen in every school, it seems unlikely that groups which evade capture would consist entirely of adult males and at least possible that they consist (as, apparently, do groups which become encircled) of clusters of affiliated subgroups representing all ages and sexes.

Behavioral observations from underwater were of vital importance to the focal animal studies and general field observations. Only a part of the school can be seen from the surface, and surfacing behavior forms a limited portion of the animals' activities, except for rafting animals. Even in clear water, it is almost impossible to follow a single individual from above for more than a few seconds. It is not easy to distinguish individuals or their activities through the air/water interface. On the other hand, if the investigator swims freely with the porpoise, individuals and groups of porpoise can be observed for as long as desired and the series of behavioral events can be easily recorded. In focal animal cases 37 and 38 (data for which will be presented in detail in future publications), Kang recorded a total of 77 behavioral events taking place between two interacting animals over a 5-minute period. Those details and extended observations add to the material available for analysis and to the investigators' ability to synthesize the data acquired. In the opinion of the investigators, such observations can only be made within the animals' medium.

The observers noted that animals that seemed to be in one state when observed from above the water might seem to be in quite a different state when observed from underwater. The observers tracked individuals and groups through the interface by moving their own heads above and below the water as the animals surfaced. Behavior observed in this way seemed anomalous and was recorded in field notes and will be discussed in detail in other reports. In general, it was felt by the observers that surface activity seemed to be misleading and difficult to interpret and did not always reflect intelligibly what was transpiring beneath the surface. Pryor and Kang are of the opinion that their underwater observations, despite the risk and rigor involved, were incontestably more informative than their observations when they were restricted to staying above the surface.

B. Tuna Olfactory Attractants[1/]

In most of the sets in which tuna attractants were tested, the tuna school did not show overt responses to the attractant. In some cases, a few fish or a small group of fish showed definite signs of arousal and interest in the attractant. However, with no other visual or auditory cues to reinforce the attractant cues (i.e., food), the responses soon faded, and fish returned to the school or to the company of porpoises.

It did not seem that the attractant, by itself, was strong enough to break the tuna/porpoise bond in the net. Unfortunately, the precise nature of the association is still not known. It does not seem to be olfactory in nature.

Tuna, observed during dye tests at backdown, displayed "bars" and excited swimming. These bars were probably associated with stress and are to be differentiated from bars seen during feeding stimulation. The color patterns are similar but the context is completely different.

[1/] Ikehara

Bars seen under odor stimulation, well before backdown, are very probably odor-induced. In both backdown and feeding, arousal and excitation are to be expected. It was interesting that in the one set in which the attractant had been tested and thawed anchovies thrown out during backdown, the fish fed readily. This is significant because, normally, tuna in captivity must be trained to take dead food.

The attractant was not tested during chase or pre-set because behavioral observations would have been difficult and strict controls impossible.

In conclusion, the attractant by itself does not seem to hold much promise in reducing porpoise mortality. It may have some value in developing alternative fishing methods. For example, odors may be effective in increasing the attractiveness of man-made aggregation devices or in behavioral modification of "breezing" tuna schools to permit purse seine operations. These will likely be the future avenues of research.

C. Purse Seine Gear Dynamics [1]

Partial net collapses, resulting from environmental factors such as swell and current, are common during normal fishing operations. The super apron area collapses more readily than other areas of the net because of the increased webbing there. These partial collapses seldom pose problems for captured porpoise because normal rolling of the net prior to backdown usually prevents these collapsed areas from increasing in size. However, if a set does not progress in a normal manner, because of malfunction or other reason, and the net is not retrieved promptly, the chances of a partial or complete net collapse increase.

The behavioral research conducted on this cruise usually required as much observation time as possible prior to backdown. The observation time was increased by rolling the net aboard more slowly than normal or stopping net roll completely for a short period of time. Thus, partial net collapses occurred, usually involving the super apron when the net was rolled aboard slowly or when the net retrieval was stopped.

There were seven sets which had partial net collapses; two of these involved porpoise of the 17 sets on this cruise. The five collapses not involving porpoise were all preceded by delayed net-rolling operations to increase behavioral research time. Future cruises requiring such procedures should expect to encounter

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[1] Bratten

an increased frequency of partial net collapses unless extensive speedboat net towing measures are undertaken. This was not done during this cruise.

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APPENDIX A

Behavior Observed in Captivity and in the Net [1/]

The behavioral events listed here are those which were contained in the computer-coded list used in data acquisition during this research. Terminology of behavior, as well as interpretations and assignments to categories, are based on a consensus of 20 experienced porpoise trainers in a survey by Defran and Pryor[2/], in press, and also on established Sea Life Park usage and terminology for behavioral events seen only in spinners and spotters.

The words "no code" indicate that the behavior did not occur in any focal animal sample case but may be known from captive animals or may have been recorded in the nets in regular field notes.

A single asterisk (*) indicates that the behavior was recorded in the nets by Pryor aboard the *Elizabeth C.J.* in 1976. A double asterisk (**) indicates that the behavior has been observed by Pryor and Kang in wild spinners in Hawaii but was not seen in the nets.

[1/] Pryor and Kang

[2/] Behavior and Training of Cetaceans in Captivity. R.H. Defran, Dept. of Psychology, San Diego State University, Karen Pryor, Dept. of Biology, New York University. Will be a chapter in "Cetacean Behavior," Louise Herman, Editor, Wiley-Interscience (in press)

Computer Code	Name of Behavior	Description	In Captivity		In Nets	
	GENERAL		Spotter	Spinner	Spotter	Spinner
RF 1	Rafting, head up	Hanging near vertical with head at surface			●	
RF 2	Rafting head downwards	Hanging motionless, near vertical, head down			●	●
ML	Milling	Whole school swimming about in one area			●	●
DV	Dive	Descends from surface head first	●	●	●	●
BR 1	Breathing	Normal respiration	●	●	●	●
BR 2	Chuffing	Sharp, puffing exhalation: alarm	●	●	●	●
BR 3	Splash-breathing	Chopping at surface to get a breath, in chase: fatigue			●	●
SW	Swim fast	Speed up in comparison to other animals; may be fear, play, other	●	●	●	●
JN 1-7	Join another	1=adult, 2=baby, 3=pair, 4=small group 5=large group, 6=juvenile, 7=mother/baby	●	●	●	●
BJ 1-7	Be joined by	Same code as above	●	●	●	●
LV 1, 2	Leave	1=animal leaves other, 2=is left by	●	●	●	●
HV	Hover	Hang motionless, horizontal in water in normal swimming attitude	●	●	●	●
BB 1	Whistle trail	"Contrail" of bubbles from blowhole; coincides with whistling	●	●	●	●
BB 2	Balloon	Basketball-sized sphere of bubbles from blowhole. Sometimes indicates surprise	●	●	●	●

APPENDIX A Continued

Computer Code	Name of Behavior *GENERAL, CONTINUED*	Description	In Captivity		In Nets	
			Spotter	Spinner	Spotter	Spinner
BB3	Balloon series	Animal releases several evenly-spaced balloons			●*	
BB 4	Unison balloon series	Pair of animals release series in unison			●*	
No code	Torus	Animal releases perfect "smoke ring" of bubbles about a foot in diameter			●	
No code	Cloud	Animal releases huge clouds of bubbles; may duck behind them and disappear			●	
A 1-9	Zap; echolocate	Click train emitted; indicated by small multidirectional movements of tip of jaw	●	●	●	●
		1=at person, 2=at other porpoise, 3=at net, 4=at tuna, 9=other				
DF	Defecate	Clouds of fecal matter released	●	●	●	●
TU	Tuna nearby				●	●
SH	Shark nearby	Not observed				
ND	Nodding	Rapid up and down head movements	●	●	●	●
PN	Pink noses	White tip of rostrum turns rosy: excitement or exertion			●	
MS 1	Miscellaneous	Shakes whole body slowly from side to side			●	

APPENDIX A Continued

Computer Code	Name of Behavior	Description	In Captivity		In Nets	
	FEAR AND DISORIENTATION		Spotter	Spinner	Spotter	Spinner
BR2	Chuffing	See "General" category				
EY	Show eyewhites	Rolling eyes, like frightened horse	●	●		
TR	Tremble	Quiver in fear: sometimes pre-shock	●	●		
TT	Teeth chattering	Fear behavior, as in many mammals	●			
BU	Bunching	Draw into tight packs, swim in unison	●	●	●	●
DS	Distress call	Rising and falling whistle emitted when animal is entangled or in other difficulty	●	●	●	●
WS	Loud whistling	Loud whistles other than distress call	●	●	●	●
PA	Panic	Animal dashes blindly about	●	●		
SG	Struggle	Trapped or entangled animal thrashes about	●	●	●	
FL	Flight	Animal flees at full speed (observed during chase but not in net)	●	●		
FE 1	Startle	Flinches at sudden move or noise	●	●	●	●
VE	Vertical bobbing	Animal hangs vertically, rising and falling	●	●	●	●
SK	Sinking	Sinking tail first	●	●	●	●
BA	Off balance	Animal flounders, falls sideways, may ship water in blowhole: extreme stress	●	●		

APPENDIX A Continued

Computer Code	Name of Behavior	Description	In Captivity		In Nets	
	FEAR AND DISORIENTATION CONT.		Spotter	Spinner	Spotter	Spinner
LY	Lying on bottom	Animal sinks to bottom and stays there; in captivity, reaction to frustration		●		
JS	Jostling	Normal "manners" are not maintained: animal bumps into or jostles others	●	●	●	●
EN	Entanglement	Trapped in a line or in netting	●	●	●	
DB 1	Disoriented "lost baby"	Spotter young: animal twirls vertically below school, whistling loudly			●	
AV 1-6	Avoidance	1=porpoise	●	●	●	●
		2=person	●	●	●	●
		3=boat	●	●	●	●
		4=net	●	●	●	●
		5=wake			●	●
		6=tuna (or other fish)	●		●	●
		9=other	●	●		
	SURFACE AND AERIAL BEHAVIOR					
TS	Tailslap	Slaps ventral surface of tail on water; irritation, annoyance, alarm, warning	●	●	●	●
HD	Headslap	Slaps head on water: usually laterally in these species: annoyance-impatience	●	●	●	●
BC	Breach	Slaps whole body sideways on water	●	●	●	●

APPENDIX A Continued

Computer Code	Name of Behavior *SURFACE AND AERIAL CONT.*	Description	In Captivity		In Nets	
			Spotter	Spinner	Spotter	Spinner
SP	Spin	Animal spins in the air on its long axis; species-typical behavior		●		●
FL	Flip	Flips tail over head in air	●	●	●	
PR	Porpoising	Arcing roll or leap at surface	●	●	●	●
TW	Tail wave	Waves tailstock back and forth in air			●	●
SB 1	Surface behavior: fluking	Animal shows flukes in air before diving	●	●	●	●
HP	Spyhop	Sticks head out of water and looks around in air; usually very brief in these species	●	●	●	●
RU	Running	Long, low, racing leaps of animals traveling at top speed; many leap at once	●	●	●	●
No code	Free-running	High, popping individual leaps, with big splashes, after leaving net			●	●
No code	Spotter display leap	Species-typical high leap, body in an S-curve traveling horizontal to water, 15 feet or more	●		●	
No code	High porpoise	Animal leaps straight up, rotates at top of jump, re-enters "same hole it came out of"	●	●	●	
No code	Unison behavior	Most of the above maneuvers may be carried out by two animals in unison	●	●	●	●
	AGGRESSION					
TH	Threat sounds	Burst-pulse			●	
		Loud click train	●	●	●	●
SN 1,2	Snitting	Sharp sidewise jerk with closed or open jaws; may be accompanied by sound	●	●	●	●

APPENDIX A Continued

Computer Code	Name of Behavior	Description	In Captivity		In Nets	
	AGGRESSION, CONT.		Spotter	Spinner	Spotter	Spinner
JW 1-6	Jaw movements	Doer: 1=gape, 2=snap receiver 4=gaped at, 5=snapped at	●	●	●	●
		3=bite, 6=bitten				
ST 1-4	Strike	1=with pectoral	●	●		
		2=with dorsal fin	●	●		
		3=with rostrum	●	●		
		4=with flukes	●	●	●	●
CH	Chase	One or several animals may chase another, or two animals may chase each other	●	●	●	●
CG 1,2	Charge	A head-on rush as if to ram	●	●	●	
RA	Ramming	Hit another animal amidships full force, head-on	●	●		
No code	Fighting	Extended exchange of blows or attacks between two or more animals (always males)	●	●	●	●
No code	Attack or strike baby	The mother herself, or other adults, may strike a baby very hard	●	●		●
	AFFILIATIVE AND SEXUAL					
HH	Hold hands	Swims with pectoral fins overlapping	●	●		● **
PE 1,2	Pectoral pat	Pat or stroke with pectoral 1=doer, 2=rec.	●	●	●	●
FU 1,2	Fluke pat	Touch or stroke with flukes 1=doer, 2=rec.	●	●	●	●

APPENDIX A Continued

Computer Code	Name of Behavior	Description	In Captivity		In Nets	
			Spotter	Spinner	Spotter	Spinner
PU 1,2,3	Push	Pushes another animal with head or rostrum	●	●	●	●
NU	Nursing			●	●*	
BG 1,2	Beak-genital propulsion	Subordinate animal places rostrum against vent of superior animal and pushes it along	●	●	●*	●
CT 1	Touch heads	Two animals hover face to face and touch or rub heads or rostrums; "kissing."			●	●
CT 2	Gentle mouthing	Usually baby to mother			●	
RB 1,2	Rub bodies	Two animals slide against each other, rubbing flank or belly on the other	●	●	●	●
PP	Chasing in pairs	Sexual play: fast, looping chases	●	●		●**
CH 3,4	Play-chase	Mock chasing, with reversals; mother/baby and juvenile play	●	●	●	
PT	Prostrate	One animal prostrates itself across another's rostrum: submissive display	●	●		
PC	Position for copulating	Male inverts himself below female	●	●		
CP	Copulation		●	●		●**
RK 1,2	Tooth-raking	One animal draws its teeth across body of the other, leaving parallel scratches	●	●	●	●
WH 1-3	Where on body	Code indicator for where raking occurred: 1=head, 2=tailstock, 3=vent				
WH 4	Raking gesture	Moving head, jaws open, back and forth in the water as if to rake				
No code	Protect or assist	Usually mother to baby; adult to adult observed in one spotter in captivity	●	●	●	●

APPENDIX B - Characteristics of porpoise subgroups observed on Cruise III, Leg 2 of the Dedicated Vessel

Type of Group	Visual Characteristics	Behavioral Characteristics
SPOTTERS Solitary Animals:	Falcate dorsal fin; spots in adult animals.	
Adult male	Keel or bulge in ventral area. Heavily spotted. White tip to rostrum. Large size.	
Adult female	Large size, heavily spotted, no ventral keel.	
Young adult male	Ventral keel. Genital slit separated. Light spotting.	
Young adult female	No ventral keel. Genital slit united. Light spotting.	
Juvenile	Smaller than adults (3/4 length of average male, up to 7/8 of average female.) No spots; equivalent of Perrin's "two-tone." Sex indicated by genital slit.	
Infant	Less than 3/4 length of adult female.	Almost always accompanied by one or more adults.
SPINNERS Solitary animals:		
Adult male	Very large, almost grotesque ventral bulge; in some animals, dorsal fin canted forwards	
Adult female	Large size, no ventral bulge	

APPENDIX B Continued

Type of Group	Visual Characteristics	Behavioral Characteristics
Young adults, juveniles	Differentiated by size only. Sex identification from genital slit, although some quite young males show beginnings of ventral keel.	
Infants	Less than 3/4 length of average adult female.	Almost always accompanied by one or more adults.
BOTH SPECIES Mother/baby pair	Adult female accompanied by young; young may be any size from newborn to as large as mother. Usually size difference and closeness and constancy of the association identify these pairs.	Two animals are in close association. Much contact and body rubbing may occur. Animals do not swim in perfect unison because of twisting around each other. May be slightly apart from and below other animals in school. Few or no aggressive signals.
Mother/baby/adult triad	Two adults with a baby between them. Accompanying adult is usually a female and usually older than the mother, but may also be a male (1 obs., spinners)	Two adults traveling quite fast with an infant sandwiched between them, often touching both adults. Adults evince alarm, swim fast, and avoid rest of school.
Mother/young subgroup	Two or more mother/young pairs with or without additional females. The presence of any infant in a group identifies a mother/young subgroup; close inspection will reveal that others in the group are either females or juvenile young, no matter how big they might have grown.	Loosely structured groups which form and dissolve repeatedly, and are characterized by mixed sizes of young present in group, and by non-unison swimming due to body-rubbing and pectoral patting both between pairs and among young and other females.

APPENDIX B Continued

Type of Group	Visual Characteristics	Behavioral Characteristics
Courting pair	Two adult animals, one male and one female, swimming together or interacting	Two animals circling, stroking, patting, whistling, nuzzling each other, touching heads or rostrums. Tooth-raking, in which male holds jaws open and passes teeth over female's body, often leaving parallel scratches, is common. Inversion and positioning for copulation indicates courtship also, but putting rostrum to the genital area may not be courtship-related. Aggressive signals may be abundant in both animals (gaping, snitting, threat displays and sounds).
Other adult pair	Two females or two males may occasionally swim together briefly.	
Juvenile subgroup	A group of smaller than full-grown individuals--without spots, in the case of spotters--sticking together closely and exhibiting much unison behavior.	Small size and near-perfect synchrony of breathing and swimming mark juvenile subgroups. These groups are also quite autonomous and do not lose or add individuals over the course of a set, as, for example, mother-young groups do.
Young adult subgroup	Males and/or females, swimming in constantly changing, merging and re-forming groups of from 3 or 4 to more than 20 animals.	The "swinging singles" set. These groups, which make up a large part of the school, do not contain babies, usually do not contain heavily spotted or very large senior adults, and fluctuate constantly in size and composition. Animals may or may not touch each other and may or may not be in unison.

APPENDIX B Continued

Type of Group	Visual Characteristics	Behavioral Characteristics
Senior male squad	3 to 8 very large males swimming in tight formation. Spotter senior males are heavily spotted and have conspicuous white flashmarks on the tip of the rostrum, which may be seen a long way off. A cluster of white dots moving by in unison indentifies a senior male squad.	Senior male squads move in unison, often shoulder-to-shoulder and with almost militaristic precision. The school parts to make way for them and they seldom divert from their chosen course. They operate almost entirely in unison, whether giving a threat, display, or investigating a strange object. They exhibit more curiousity and more aggression than other kinds of groups, and may make oddly ritual-istic threat displays at human divers.