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USING TUNA-VESSEL OBSERVER DATA TO DETECT TRENDS IN ABUNDANCE OF DOLPHIN POPULATIONS: HISTORY AND RESEARCH TO DATE (1988)

Elizabeth F. Edwards

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U.S. DEPARTMENT OF COMMERCE
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USING TUNA-VESSEL OBSERVER DATA TO DETECT TRENDS IN ABUNDANCE OF DOLPHIN POPULATIONS: HISTORY AND RESEARCH TO DATE (1988)

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ABSTRACT

Scientific observers aboard tuna purse-seiners in the eastern tropical Pacific Ocean (ETP) record sightings of marine mammals, in particular sightings of dolphin schools that are sought by tuna fishermen because of the strong association between these schools and schools of large tuna. These "tuna-vessel observer data" (TVOD) provide a controversial basis for detecting trends of abundance in the affected populations of dolphins.

This report summarizes the history of TVOD collection and its uses by the two agencies responsible for detecting trends in dolphin abundance in the ETP; the National Marine Fisheries Service (NMFS) and the Inter-American Tropical Tuna Commission (IATTC).

The report describes development and current state of the "tuna-dolphin" fishery, research programs conducted by each agency, problems found with using TVOD in analyses conducted to date, and the types of data collected. Although the topic is specific to the eastern tropical Pacific fishery, TVOD analysis is in many ways a generic example of the struggle to derive adequate estimates of stock abundance from commercial fisheries data. Thus the report has both a specific and a general objective. Specifically, the report serves as introduction and entry into the literature for researchers interested in analysis of TVOD but unfamiliar with it's extensive background. Generally, the report serves as an example of the types of problems commonly arising in fisheries analysis, and the solutions that have been and are being developed to remedy, at least in part, these vexing problems.

INTRODUCTION

Dolphins are inadvertently killed during fishing operations by the tuna purse-seine fleet in the eastern tropical Pacific Ocean. This report chronicles efforts to use data collected by scientific observers aboard those vessels, to monitor trends in the relative abundance of the affected dolphin stocks (hereafter referred to as "monitoring" the stocks).

This monitoring of dolphin stocks has been a legal responsibility of the United States National Marine Fishery Service (NMFS) since 1972 and since 1979 a voluntarily selected focus of research by the Inter-American Tropical Tuna Commission (IATTC). NMFS monitors the dolphin stocks in order to set annual quotas on incidental mortality due to the fishery. IATTC monitors the stocks in conjunction with their primary charge to provide advice to management about commercial tuna stocks in the ETP. Although both NMFS and IATTC collect tuna vessel observer data (TVOD), NMFS also collects monitoring data during research surveys conducted specifically for this purpose (RSOD; research survey observer data). NMFS has not relied on TVOD as the sole means of monitoring dolphin stocks because, unlike research survey vessels, the course and speed of tuna vessels fishing commercially cannot be controlled rigorously. Subsequent to amendments to the MMPA in 1984, NMFS developed a three-faceted approach to monitoring dolphin stocks in the ETP, relying on RSOD, TVOD, and life history material collected by observers on U.S. tuna vessels.

In using RSOD and TVOD to monitor dolphin stocks, Line Transect Analysis methods (LTA) are used. The sighted objects are dolphin schools and the trackline is the path taken by either a survey platform (aircraft or vessel) as it follows a pre-determined course or by a purse-seiner as it searches for tuna. Proper application of LTA depends upon satisfying a number of assumptions about relationships between objects and sighting platforms, and about data collection procedures (e.g., Smith 1975, Laake 1981, Hammond and Laake 1983, Holt 1987a, 1987b).

Observers on both research and commercial fishing platforms record the same types of data for subsequent LTA. However, NMFS researchers consider RSOD more reliable than TVOD because RSOD are collected under carefully controlled experimental protocols. This is not the case for TVOD. TVOD are collected during commercial fishing operations, which means that observers on tuna vessels cannot control the search path of the vessel and must usually rely upon crew members to report sightings. This lack of control and need to rely on crew reports appears to seriously violate several of the major assumptions required by line transect analysis (e.g., Smith 1975, Polachek 1983, Hammond and Laake 1983, Buckland and Anganuzzi 1988).

This is unfortunate because TVOD are much more abundant than RSOD. Although only one or two research surveys are economically feasible during any given year, the tuna fleet generally comprises over 100 large purse-seiners. These vessels spend most of their time at sea actively searching for tuna (and encountering dolphin schools). Usually at least a third of the boats carry scientific observers collecting mortality and sightings data.

This abundance of data from a legally-mandated and relatively inexpensive sampling program led NMFS in 1986 to begin a new program, as part of their three-facted approach to monitoring dolphin stocks in the ETP. The program's objective is to evaluate quantitatively the utility of TVOD for estimating trends in abundance of dolphin populations (Reilly 1987).

With this new emphasis on TVOD, NMFS anticipates drawing on the abilities of researchers not previously involved with the tuna-dolphin problem. Because of the complexity of the data set and its extensive history, the following report was prepared to summarize the past and present state of the tuna-dolphin problem.

The report has also another, more general purpose. In addition to providing a description and chronicle of efforts to assess status of dolphin stocks in the eastern tropical Pacific Ocean, this report serves as a guide to a major block of marine mammal data and research. Since 1972, tuna-dolphin research activities in the ETP have provided the impetus for development of many techniques now used world-wide in cetacean assessment programs. These techniques include, in particular, refinements of line transect analysis for deriving estimates of cetacean abundance from sightings data (e.g., Smith 1983, Hammond and Laake 1983, Holt 1987a, 1987b, Buckland and Anganuzzi 1988). In addition, ETP tuna-dolphin research provided the impetus for the definition of Optimum Sustainable Population used currently in the Marine Mammal Protection Act (T. D. Smith, Northeast Fisheries Center/NMFS, Woods Hole, MA; pers. comm).

The sheer volume of data, collected for almost 2 decades and ranging from sightings data for point estimates of abundance to complete (all ages well-sampled) life history data for estimates of population dynamics, is un-matched for any other assemblage of cetaceans. The data base and historical record provide an unprecedented source for investigating general principles of marine mammal population dynamics and ecology, and marine mammal-fisheries interactions, in addition to NMFS' focus on stock assessment.

This report provides the only comprehensive introduction to and summary of the available data and research conducted to date. Such a review and summary did not previously exist, making it quite difficult for anyone not involved already in the problem to grasp quickly the relevant details. The report is not intended to provide an exhaustive critical review of the tuna-dolphin problem, but rather to serve primarily as a convenient source of summary information and an entry point for more detailed studies.

Following this introductory section the report summarizes 1) the history of the tuna-dolphin fishery, 2) research conducted to date (and proposed) by NMFS and by IATTC, 3) problems recognized or suspected in the data or data analyses, and 4) the types of data that have been collected. Included as an Appendix is a chronological listing of research surveys.

Throughout this report, the terms "dolphin" and "porpoise" are used interchangeably. Porpoise was the preferred term in earlier years; it has been replaced more recently by dolphin.

HISTORY OF THE TUNA-DOLPHIN FISHERY

Types of Tuna in the ETP

Most tuna caught by purse-seiners in the ETP are either skipjack (*Katsuwonus pelamis*) or yellowfin (*Thunnus albacares*). Skipjack are relatively small (less than 50 cm fork length) and occur primarily in large schools. Yellowfin grow larger, up to about 160 cm in length. Yellowfin appear in surface fisheries in the ETP at about 40 cm total length and disappear when about 130 cm, moving then into deeper waters where they are captured by long-liners.

Types of Tuna-fishing in the ETP

Tuna purse-seiners in the ETP generally practice one of three types (sometimes called "modes" e.g., Hammond and Laake 1983) of fishing; 1) school fishing, 2) log fishing, and 3) dolphin fishing. School fishing captures skipjack and relatively small yellowfin (40-80cm), generally within 100-200 miles of the coast. Schoolfish are located by looking for flocks of associated birds or for disturbances at the water's surface caused by feeding tuna or birds. Schoolfish are captured by surrounding as much of the school as possible with the purse-seine. Log fishing captures tuna by using the purse seine to surround floating logs or other debris, together with any tuna accompanying the log. These "logfish" can be of any size, but tend to be more similar in size to the schoolfish than to tuna found associated with dolphins.

The dolphin association occurs almost exclusively with the larger yellowfin or "dolphin fish" (80-130 cm fork length). Fishing "on dolphin" involves two phases. Dolphins (or associated bird flocks and subsequently dolphins) first provide a sighting cue to the presence of tuna schooling beneath the surface. After bringing the purse-seiner within a couple of miles of the school, speedboats are launched. These speedboats are used to drive the dolphin school into a milling herd which the purse-seiner then approaches and surrounds with the net. These speedboats are used only in "dolphin fishing". The strength of the tuna-dolphin association is such that the tuna remain with the dolphins even during the chase and subsequent capture (e.g., Perrin 1968, 1969).

The searching phase of tuna fishing in the ETP is conducted with two to four high power (20-25X) binoculars mounted on the flying bridge and mast of the purse-seiner, plus a helicopter if the vessel is large enough and can afford it. Although helicopters were rare in the mid-70's, most large vessels today (1988) have one. Searching is conducted from sunrise to sunset every day that weather permits on the fishing grounds, and usually as vessels travel to the grounds (Edwards 1989).

Advent of Purse-seining and Dolphin Fishing

Prior to about 1960, tuna-fishing in the ETP involved relatively small boats fishing within 200-300 miles of the western coasts of Central and South America, from about 10°N to 10°S (Joseph 1970). Fishermen on these boats caught individual tuna with baited pole-and-line (Howard 1964, Johnson 1964, Joseph 1970, Green et al. 1971, Orbach 1979). In this pole-and-line fishery, dolphin were simply one of a suite of cues to the presence of tuna. Dolphins were not involved in the actual capture of the fish, so incidental mortality of dolphins was not a problem.

The situation changed completely between 1958 and 1961. During this 3-year period, virtually the entire U.S. fleet converted from pole-and-line fishing to purse-seining. Fishing with purse seines was attempted as early as 1914 (Green et al. 1971), but limitations in net materials and machinery relegated this mode of fishing to a very minor component of the entire fishery. These limitations were overcome by technological advances in net materials and net-handling machinery during the late 1950s. In 1950, seiners comprised only 25% of the tuna fleet (67 of 271 vessels); in 1963, seiners comprised 80% of the fleet (111/141, Johnson 1964). By 1981, seiners comprised 98% of the international fleet (283/289, IATTC Annual Report 1981).

Capitalizing on the strength of the tuna-dolphin association, the practice of capturing tuna by capturing schools of dolphin spread rapidly through the fleet. By 1966, 62% of all yellowfin tuna caught by U.S. purse-seiners were caught with dolphins (Perrin 1969b). The percentage has remained between 50% and 96% since then (IATTC Annual Reports 1966-1987).

Subsequent Changes in Fleet Composition and Distribution

Significant changes have occurred in the purse-seine fishery since it's inception in the mid-1960s. The fishery has expanded progressively further offshore and the major ports for unloading fish have moved from California to the western Pacific (primarily American Samoa) and Caribbean (Puerto Rico). Also, the national composition of the fleet has changed from primarily U.S. registry to about one-third U.S. and one-third Mexican, with several other countries comprising together the other third (IATTC Annual Reports, 1966-1987).

At least four factors contributed to the fisheries' offshore movement: 1) the tuna are larger and the tuna-dolphin association is more prevalent (SWFC 1972); 2) tuna vessels became progressively larger (IATTC Annual Reports) and thus able to remain at sea longer and fish further from the coast; 3) from 1966 to 1980, the inshore area (CYRA; Commission Yellowfin Regulatory Area) was closed to fishing for yellowfin tuna during the latter half of most years, under regulations set forth by the IATTC (IATTC Annual Report 1981), thus forcing boats to fish further offshore after closure of the CYRA, and 4) in response to the Fishery Management and Conservation Act (FMCA) of 1977, Mexico established it's own 200-mile coastal zone, excluding U.S. vessels (the majority of the fleet at that time) from fishing these previously popular nearshore areas. Non-US vessels accounted for only 2% of fishing on dolphin in 1970. This increased to 12% by 1975 (SWFC 1975) and 64% (151/158 vessels) by 1986 (IATTC Annual Report 1986).

By the end of the 1960s, the predominately coastal fishery had expanded from relatively near-shore zones to areas much further offshore, near the boundaries of IATTC's Commission Yellowfin Regulatory Area (CYRA, Figure 1). By the early 1970s, seasonal fishing outside the CYRA after closure was commonplace (IATTC Annual Report 1981). Although the majority of fishing for yellowfin tuna still occurs within the CYRA, this westward expansion increased the percentage of total catch (short tons) collected in the outside area from 0% (0/90,000 short tons) in 1967 to 28% (50,000/178,000) in 1973. This percentage decreased subsequently to 20% (29,000/147,000) in 1981 and 10% (23,000/217,000) in 1985 (Table 1, IATTC Annual Report 1985), but these offshore areas still account for a large fraction of the total sets on tuna with dolphins because in these areas most tunas caught are associated with dolphins. Fishing has been relatively heavy year-round in the CYRA since the effective demise of the closure system in 1980 (IATTC Annual Report 1985).

A different type of area expansion occurred in 1983, when many U.S. purse seiners chose to fish in the western and central Pacific instead of in the ETP. This was due in large part to failure of the ETP surface fishery during the major El Niño of that year. Finding relatively little success in the west, vessels tended to return eastward in 1984 (Marine Mammal Commission Annual Report 1985, IATTC Annual Reports 1985-1987). Vessels remaining in the western Pacific fish primarily for schoolfish, because the tuna-dolphin association does not persist that far west. These western Pacific "residents" reduced the number of seiners fishing on dolphin in the ETP, but the high prices paid for the large yellowfin associated with dolphin encouraged the majority of the vessels to return eastward.

In addition to the westward "exploratory" expansion (IATTC Annual Reports, Patterson and Alverson 1986) the fishery has expanded also southward since 1976, encountering new and possibly distinct stocks of dolphin associated with tuna.

The move to ports outside the continental U.S. (primarily to American Samoa and Puerto Rico) was precipitated by increasing labor and other costs in the U.S. compared to the other areas. The change in the international composition of the fleet resulted in part from increased restrictions and expenses for boats under U.S. registry, but Mexico's expansion of her tuna fleet was a primary factor. In addition to excluding U.S. boats from it's 200 mile exclusive economic zone (EEZ), Mexico increased dramatically the size of it's tuna purse-seine fleet from 20 purse-seiners in 1975 to 45 in 1986 (IATTC Annual Reports 1975, 1986).

The continuing increase in the number of non-U.S. purse-seiners is significant because relatively little is known about dolphin mortality caused by non-U.S. boats. U.S. vessels have been required since 1974 to carry NMFS observers if requested (SWFC 1976) but observers have been placed on non-U.S. vessels only since 1979 and on only a small fraction of the total non-U.S. fleet. Until recently, observers have usually accompanied only 5-10% of all trips by non-U.S. purse-seiners (IATTC Annual Reports 1979-1987). Until 1985, no observers were permitted on Mexican vessels, despite the fact that these vessels have increased to 30-40% of the total fleet and have, because most of the Mexican vessels are "super-seiners" (greater than 1000 ton capacity), a total capacity exceeding the U. S. fleet. However, since Mexico's joining of the IATTC's observer program in 1986, coverage of the non-U.S. fleet has increased to average about 35% with a majority being coverage of Mexican vessels (IATTC Annual Reports 1986-1988).

Generally fewer restrictions or other incentives to reduce mortality of dolphins by the non-U.S. fleet has led to some suspicion that mortality may be a greater problem on non-U.S. than on U.S. vessels. In 1986, for example, the estimated total mortality of dolphins due to U.S. vessels was about 20,500 animals (the quota was reached), but the estimate for the entire international fleet (including U.S. vessels) was 5 times larger, about 125,000 animals. Thus U.S. vessels were responsible for only one-sixth of the total mortality, although U.S. vessels comprise about one-third of the total international fleet.

However, it has also been noted (Hall and Boyer 1986) that dolphin mortality rates are not constant over area and this factor must be considered in computing rates of mortality by country.

Purse-seine fleet capacity has increased considerably during the last 20 years. It was 49,000 tons in 1965, increasing to a maximum of 189,000 tons in 1980. Capacity has decreased since then to 123,000 tons in 1986 (IATTC Annual Reports), but is still over twice it's level 20 years earlier. After a substantial increase early in the development of the purse-seine fishery, from 600 sets in 1959 to 7,000 sets in 1965, the total number of sets on dolphin has remained relatively stable, fluctuating between 7,000 and 10,000 sets per year from 1965 through 1981, the last year IATTC reported this statistic.

The sizes of tuna caught have also fluctuated noticeably, perhaps as a result of these changes in areas fished, fleet capacity, and fleet registry. For example, large fish (longer than 60 cm) predominated in catches during 1973; in 1981, the catch was composed mostly of relatively small fish (40-60 cm; IATTC Annual Report 1981). Weight of individual captured tuna was about 80 pounds during 1972-1977, but only about 60 pounds during 1977-1981 (IATTC Annual Reports). Because the tuna associated with dolphin are predominately large yellowfin, these increases (or decreases) in size of tuna caught imply concomitant increases (or decreases) in fishing pressure on dolphins.

These changes in the characteristics of the fishery imply that the effect of the purse-seine fishery on dolphin populations in the ETP has been significant but variable during the last 27 years (1960-1987). Two agencies are actively involved in trying to quantify that effect; NMFS and the Inter-American Tropical Tuna Commission (IATTC), an international organization responsible for management of all commercial tuna stocks in the ETP. Histories of each agency's research programs follow.

NMFS RESEARCH PROGRAM

General History

The practice of catching tuna by purse-seining schools of dolphins led to estimated annual mortality of several hundred thousand dolphin each year in the ETP during the late 1960s (Perrin 1968, 1969a, 1969b). This was first witnessed by NMFS personnel conducting unrelated research aboard tuna vessels in 1966 (Perrin, pers. comm.). In response to the observed mortality W. F. Perrin, a fishery biologist at the NMFS Southwest Fishery Center (SWFC) in La Jolla, CA, submitted in 1969 a research proposal to the SWFC Director, requesting funds to assess and eventually mitigate this incidental mortality of dolphins. The proposal was funded in 1970. This was the beginning of a research program that grew over the next decade to become a major part of the Center's activities each year.

The SWFC tuna-dolphin research program began officially in February 1970 with two major foci: 1) gear research, to decrease the incidental kill as quickly as possible, and 2) population dynamics research, to assess the effect on the dolphin populations of the incidental kill. While becoming substantially more complex in detail, these remained the organizing foci for tuna-dolphin research at the SWFC through 1979 (SWFC 1972, Barham 1974, Perrin et al. 1974, Smith 1975, Smith 1979). By that time, improvements in gear and purse-seining procedures (specifically the small-mesh Medina panel and the backdown procedure) had reduced dramatically the annual incidental kill, from about 300,000 animals/yr in the early 1970s (SWFC 1972) to less than 20,000 in 1980. Gear research was phased out, but NMFS research on various aspects of population dynamics has continued through 1988 (Holt and Powers 1982, Smith 1983, Barlow and Holt 1984, Cologne and Holt 1984, Holt 1984b, 1985a, 1985b, 1987a, 1987b).

Data sources for these gear and population dynamics studies have included: 1) RSOD, 2) TVOD, and 3) data collected during chartered cruises by tuna vessels (listed chronologically in Appendix). The NMFS observer program began collecting TVOD on a "guest" basis in 1971, but was mandated by law for U.S. purse-seiners in 1972. Since that time, tuna vessels registered in the United States have been required to carry observers if requested by NMFS. The only exception to this rule occurred during 1983, when the observer program was temporarily suspended by court order initiated by members of the fishing community. The observer program was re-instated in 1984, and continues through the present (1988).

The number of trips observed has varied annually, from less than 10 to over 100, with coverage of trips by U.S. seiners ranging from 0% (in 1983) to near 100% (in 1986; see Appendix). RSOD have been collected approximately annually during aerial and research vessel surveys since 1974 (see Appendix). Charter vessel data were collected primarily for gear research and other studies un-related to estimates of dolphin abundance, and are not considered further here.

NMFS researchers have tended to use RSOD and TVOD for different purposes. Although NMFS estimates of <u>area inhabited</u> used all sightings from both TVOD and RSOD (Au and Perryman 1982, Perrin et al. 1985), NMFS estimates of <u>school density</u> (schools/1000 square kilometers) have been drawn almost exclusively from RSOD. TVOD have been used primarily for two other purposes, 1) studies of life-history parameters such as age-frequency distributions (Barlow and Hohn 1984), growth rates (Perrin et al. 1976, 1977; Reilly and Barlow 1986), and pregnancy rates (Barlow 1984, 1985), and 2) estimates of school size (Holt 1985a, 1985b) and species proportions (Barlow and Holt 1984, 1986).

NMFS research relevant to detecting trends in abundance of dolphins in the ETP is discussed below chronologically by year. The results of life history studies and gear research have not been used directly in previous estimates of abundance or trends in abundance, and so are not discussed further here, although life history studies may play a larger role in future analyses. In 1986 NMFS began analyzing life history data to test hypotheses about relationships between life history parameters and trends in population size. If successful, observed relationships may be used to determine whether any observed decreases in dolphin abundance are related to activities of the U.S. tuna fleet. This research is currently on-going (1988) and is not discussed further here.

Also in 1986, NMFS began a 6-year series of annual surveys designed to determine trends in dolphin stocks, in anticipation of an assessment of stock status required in 1992. These are strictly research surveys and are currently (1988) on-going. Although the data will be used in comparative studies of TVOD collected concurrently, these comparative studies are at this time in preliminary stages only, and are not discussed further in this report.

1972: NMFS's First Estimates of Abundance

In 1972, NMFS researchers produced the first estimates of trends in dolphin abundance (all species combined) in the ETP, using data collected by the IATTC to estimate an "index" of trends (year-to-year changes in abundance) rather than actual abundance (SWFC 1972). NMFS used IATTC data because prior to the beginning of the SWFC tuna-dolphin research program, IATTC was the only agency collecting data from the tuna fleet in the ETP (see Joseph 1970 for a review of the tuna fishery up to 1969). The data used by NMFS consisted only of number of sets made on porpoise (dolphin) schools per month per statistical subarea; the index was simply "number of dolphin sets per Adjusted Standardized Days Fishing for each year" (ASDF, an index of fishing effort) for each year.

NMFS found no consistent trend in the index, but had no confidence that the result reflected actual events because interpreting this estimate of encounter rate was confounded by changes in the length of the fishing season and by geographic expansion of the fishery (SWFC 1972). Smith (1975) later recalculated the index adding years 1971 to 1973 and found the later indices to be lower (about 60% of the average during 1963-1970). But again, little confidence was placed in the result. Smith (1975) lists 4 other un-quantified factors, in addition to an actual change in encounter rate, that could have produced the observed decrease in the index. These were "1) changes in the efficiency or fishing technique of the tuna vessels in catching tuna with porpoise, 2) changes in the number and size of porpoise schools, 3) changes in the frequency and amount of yellowfin tuna associated with porpoise schools, and 4) changes in the behavior of porpoise (NMFS 1974, pg. 128)". Use of ASDF as an index of porpoise abundance was subsequently abandoned.

1974: NMFS's First Research Survey; NMFS's First Estimates for Single Species

In 1974, NMFS produced the first two sets of species-specific estimates of dolphin abundance (Clark 1974, Smith 1974). Both sets of estimates were derived by line transect analysis (LTA), this method of stock assessment having been selected by NMFS as the most appropriate method for estimating dolphin abundance (Smith 1975).

One set of estimates was derived from TVOD collected during January, February, and March 1974 (Clark 1974). This was NMFS first attempt to apply LTA to TVOD. Clark (1974) used only TVOD to estimate all the parameters needed for line transect estimates of abundance (i.e., school density, average school size, area inhabited, and species proportions of mixed schools). Discussion focused on the estimates of school density because this is the only parameter derived specifically from LTA; the other parameters are simply multipliers on the basic estimate of school density (e.g., Holt 1985a). The major problem with using TVOD for deriving estimates of abundance from LTA was perceived to be the non-random search paths followed by tuna vessels (SWFC 1972, Clark 1974, Smith 1974, Barham 1974).

Aerial surveys appeared to offer a satisfactory alternative to TVOD and had been suggested earlier as the most efficient method to derive population estimates as quickly as possible (SWFC 1972). Thus the second set of estimates drew data from two sources: 1) an aerial survey conducted along the coasts of Mexico and Central America during January and February 1974, and 2) TVOD collected during 1973 (Smith 1974). This second set of estimates was NMFS's first use of aerial survey data to derive estimates dolphin abundance from LTA. Smith (1975) used the aerial survey data rather than TVOD to estimate school density because of serious reservations about using TVOD for LTA. These reservations stemmed from 1) non-random (contagious) distributions of sightings (i.e., non-random encounter rates, which may or may not indicate non-random distribution of schools (Smith 1975)), 2) dependence of observers on crew for first reports of school sightings (important because crewmen may not report small schools potentially carrying few tuna, or schools of species that usually carry no tuna), 3) inaccurate estimates of sighting distance and angle (which can severely affect estimates of school density derived by LTA from these measurements), and 4) concentrated non-homogeneous effort (as evidenced by zig-zag, or criss-crossing vessel tracks; this may lead to double-counting of schools, in addition to being non-random). Both authors recommended against the use of TVOD for estimating absolute abundance.

However, Smith (1975) did use TVOD to estimate average school size and species composition, because the data from the aerial survey were relatively few but TVOD were plentiful and because biases from TVOD were perceived to be less severe for these other two parameters.

In October 1974, NMFS produced an extensive review of the tuna-dolphin research program from 1972 through 1974 (Barham 1974; Perrin et al. 1974). Included in the review is a comparison of the two sets of abundance estimates produced by Smith (1974) and Clark (1974). As expected from the non-random distribution of both dolphin schools and fishing effort, the higher encounter rates of dolphin schools by tuna vessels produced abundance estimates from TVOD that were higher than abundance estimates derived from the aerial survey (15% higher for spotted dolphin, 25% higher for spinner dolphin).

This review (Barham 1974) also presents, in addition to Smith and Clark's species-specific estimates of current abundance, estimates of historical trends in abundance (expressed as sets/Adjusted Standard Days Fishing (ASDF)). These historical trends were calculated once again from the IATTC data, after various adjustments to the definition of effort (Barham 1974). Definite trends were apparent but as before, artifact could not be distinguished from fact and the approach was subsequently abandoned.

1975: First Extensive Tests of Line Transect Assumptions

In July 1975, NMFS (Smith 1975) produced 2 new point estimates and 4 new interval estimates of abundance for offshore spotted and eastern spinner dolphins based on LTA of sightings data. One or more of three types of data were used in the analyses; TVOD, aerial survey data, RSOD. A variety of tests were completed to investigate various violations of LTA assumptions. The point estimates were derived only from TVOD collected during 1974. The interval estimates were derived from a subset of 9 different estimates of school density. One of these 9 estimates was based only on data collected during the 1974 aerial survey, 4 were based on a combination of RSOD and TVOD collected during 1974, and 4 were based on a new approach combining all three types of data (Smith 1975).

Smith (1975) followed Clark (1974) and Smith (1974) in using line transect methods to estimate abundance, but tested the data more completely for failures to satisfy assumptions required by line transect analysis. As before, the spatial distribution of dolphin schools was significantly non-random in both aerial survey data and TVOD. In addition, TVOD fit poorly the desired exponential sighting function, and the average sighting distance varied greatly (from 0.4 to 4.1 nm) from ship to ship. By implication, effort was effectively non-uniform so that ships could not strictly be considered replicates.

Smith (1975) also found that school size estimates differed between years, between observers vs. crew, and between northern vs. southern geographic areas. Lacking any better alternative, he estimated average school sizes for spotted and for spinner dolphins as the weighted average of school sizes in 1974 TVOD, stratified (and weighted) into 9 geographic subareas.

Smith (1975) then chose 4 of the 9 school density estimates (highest, lowest, and 2 middle values) and calculated 4 interval estimates of population abundance for each species of dolphin. Each interval estimate was calculated as the product of one of the 4 school density estimates, the estimated average school size for each species, and the known geographic range of each population. The population estimates derived from the two middle-value estimates of school density were considered to be the best estimates currently available.

The school density estimates incorporating both aerial survey data and TVOD introduce a device that has been used often in subsequent dolphin assessments. For areas where only TVOD are available, pseudo-survey estimates are generated by "calibrating" (Holt and Powers 1979, 1982); i.e., adjusting TVOD-only estimates with data from areas where both survey data and TVOD have been collected. The basic assumption in this approach is that the ratio of RSOD density estimates (RSODE) to TVOD density estimates (TVODE) from areas where both were measured (e.g., area 1) is the same as in areas where only TVOD were collected (e.g. area 2). That is,

$$\frac{(RSODE)_1}{(TVODE)_1} = \frac{(RSODE)_2}{(TVODE)_2}$$

The only unmeasured component of the ratios ($RSODE_2$) can be estimated as:

$$(RSODE)_2 = \frac{(RSODE)_1}{(TVODE)_1} * (TVODE)_2$$

TVOD are thus used only as <u>indices</u> (correction factors) rather than as their absolute values. These ratios are unique in incorporating both survey and TVOD in a single analysis. Although Smith (1974) had used both TVOD and survey data in his previous analysis, only one type of data had been used for any one type of estimate. Aerial survey data had been used for estimating school density, and TVOD had been used for estimating school size and species proportions. In 1975, Smith (1975) combined both survey data and TVOD into a hybrid, "calibrated" estimate of school density, in 3 of the 9 types of school density estimates calculated.

This hybrid approach was used because the TVOD were demonstrably biased but were available from a much greater fraction of the dolphin's inhabited range, while the aerial survey data were relatively unbiased but were available only from shoreward areas. The estimates of total abundance in Smith (1974) were derived by simply assuming that school density in the entire range was the same as that measured in the nearshore areas during the aerial survey. In the later analysis incorporating both TVOD and survey data, this assumption was not necessary. If TVOD indicated a decrease in abundance with distance from shore, this decrease would be reflected in the ratio-derived estimates, as a proportional decrease in the "calibrated" survey estimate.

In August 1975 this work was summarized in the current year's progress report (SWFC 1975).

In December 1975, NMFS issued the first permits to the tuna industry legally allowing U.S. vessels with a Certificate of Inclusion to fish on dolphin (SWFC 1976). In May 1976, these permits were voided by Judge C. Richey, who ruled that NMFS had not met certain legal requirements of the MMPA in issuing the permits. In particular, NMFS had not produced the required comparisons between existing and optimum sustainable population (OSP) sizes. Although fishing on dolphin never actually had to stop in 1976, NMFS did obligate itself to, among other things, calculate the comparisons between existing population sizes and OSP for each of the species of dolphin involved in the fishery. Up to this time, NMFS had produced estimates only for stocks of offshore spotted and eastern spinner dolphins, and had not determined an OSP level for any species (Clark 1974, Smith 1974, Smith 1975).

1976: First Status of Stocks Workshop (SOPS #1)

In July 1976, a workshop was held at SWFC to assess the status of all dolphin species involved in the ETP tuna purse-seine fishery. Workshop participants first agreed upon a general definition of OSP for cetaceans involved in the purse-seine fishery, then estimated both current population levels and pre-exploitation levels in 1959 prior to development of the purse-seine fleet (SWFC 1976). These pre-exploitation population levels were assumed to be the maximum OSP level within the hypothesized range of possible levels. The estimates of OSP were derived from a simple recursion model, starting with estimated current abundance and "backing up" through time, using estimated rates of reproduction and natural mortality, and records or estimates of fishing-related kill during each preceding year. Workshop participants then compared the estimated current and OSP levels for each species and determined a level of kill below which the species population should increase.

Current population sizes were estimated using data from the aerial survey in 1974, and TVOD from 1974, 1975, 1976. As in Smith (1975), "biases in the shipboard survey relative to the aerial survey were recognized and adjusted for by means of a ratio correction. This ratio was the population estimate derived from the aerial survey in 1974, divided by the estimate derived from TVOD collected during the same period (January-February 1974)" (Fox 1976, Appendix 5). Only TVOD from January and February 1975 and 1976 were used in the estimates of school density. A ratio correction was also used to adjust the perpendicular distances derived from TVOD from 1975 and 1976, when changes from one year to the next in data recording procedures caused biases in this estimate. Geographic range of known sightings was expanded from Smith (1975) to include sightings data collected through 1976.

Exact procedures for estimating abundance varied between species. Several more ratio corrections were used to account for seasonal differences and differences in estimated range. Although the report includes estimates based on aerial surveys and on TVOD, the group preferred the estimates from the aerial surveys, citing more inherent problems with TVOD, which they called at this time "shipboard surveys" (Fox 1976, Appendix 4).

These inherent problems perceived to plague TVOD included 1) failure of sightings data to fit an exponential sighting function, 2) possible failure to sight every school on the trackline, 3) possible non-random search effort by tuna vessels <u>within</u> strata, either because of boat to boat communication, or because tuna vessels attempt to encounter as many tuna schools as possible, 4) possibility of re-sighting schools, 5) differences between years in instructions given to observers (during 1975 and 1976, but not 1974, time of sighting was taken incorrectly to be the time at which dolphins were actually seen, even if the school had been discovered earlier because of associated birds), and 6) differences in school size estimates from tuna vessel crew compared to observers on survey platforms.

1977: Judicial Hearings; Fleet Leaves Late

Following Judge Richey's decision in May, NMFS published in the Federal Register on October 14, 1976 a new set of proposed regulations, and announced a hearing at which contesting parties could argue in the presence of an administrative law judge the pros and cons of the new regulations. These hearings took place in San Diego, CA and Washington, D.C. at various time between November 15 and December 4, 1976. On March 1, 1977 the new regulations and an extensive discussion of events leading to the new regulations were published in the Federal Register (Vol. 42(40): 12010-12020).

Essentially, the assessments produced by the NMFS workshop in July 1976 (updated where additional information had been received) were accepted. Eastern spinner dolphins, Costa Rican spinner dolphins, and coastal spotted dolphins were ruled "depleted", prohibiting tuna fishermen from setting on these species. Quotas were announced for the other species. These proceedings prevented permits being issued to the U.S. tuna fleet until 15 April 1977. The fleet didn't actually leave port that year until mid-May.

From February 28 through March 2, 1977 the SWFC held a workshop to assess research related to the tuna porpoise problem (Ralston 1977). No new analyses were presented but 1) plans were announced for a major research survey utilizing three different survey platforms (airplane, research vessel, and tuna vessel) to be conducted during January through June 1977 and 2) preliminary results were presented from a study conducted during 1976 aboard the research vessel *Surveyor*. The proposed research survey was to provide estimates of dolphin density and abundance, and to delimit stock boundaries.

The *Surveyor* cruise had not been a research survey, but had been designed to test the response of dolphin schools to an approaching ship. This is important because population density estimates derived from line transect data depend critically on the assumption that sighted objects do not change their position in response to the sighting platform, at least not prior to being sighted (Burnham et al. 1982, Laake 1981). Preliminary results from the *Surveyor* study indicated that schools changed their course at a distances up to 6 nautical miles from the approaching ship (Au and Perryman 1982), but that reaction distances of 2-4 nautical miles were more common. This is well within the 6 to 7 mile sighting horizon of observers on tuna and research vessels, and implies that observers probably sight most schools before the schools react to the ship.

The combined airplane/research vessel/tuna vessel survey was a limited success because the research vessel survey was the only component that actually operated according to schedule. This was completed by the research vessels *Jordan* and *Cromwell* between 4 January and 25 March. Mechanical problems delayed parts of the aerial survey through June. The delay in issuing permits prevented the tuna fleet from occupying the survey area during the survey period as they normally would have done.

After the surveys were completed, an *ad hoc* committee of experts on population estimation and line transect theory developed plans to analyze the data collected during the surveys. The committee identified further problems with the data that required additional field work (these problems included excessive aircraft speed and changes in type of aircraft during the survey). The group then helped design a second survey, to be conducted in 1979. This second survey would involve two research vessels and an airplane better suited for aerial surveys.

In August 1977, another set of hearings were held, this time in response to new regulations proposed for the 3 years 1978-1980 (SWFC 1977). The data from the research surveys were not yet available, so with the exception of whitebelly spinner dolphins, revisions of population estimates were relatively minor.

Prior to these hearings, IATTC completed their own stock assessments and derived considerably higher estimates of abundance. But IATTC's estimates were derived from TVOD alone, and were uncorrected for the various biases found in the data by NMFS. After applying to the IATTC estimates corrections similar to those applied in the NMFS analysis, the disparity between NMFS and IATTC estimates was relatively small (-14 to 8%).

On the basis of these assessments, regulations and quotas were issued for the years 1977 through 1979. Between August 1977 and August 1979, 4 workshops were held at SWFC in preparation for a new report on the status of each dolphin stock affected by the ETP purse-seine fishery. This new Status of Porpoise Stocks report (SOPS #2) was required in order to issue new regulations and quotas for the years 1980 to 1985 (Holt and Powers 1979).

1978: School Size Estimations (Brazier, Clark)

During 1978, no new assessments appeared, but TVOD figured prominently in a contract report presenting a "Statistical Analysis of Porpoise School Size Estimating Data from the Eastern Tropical Pacific Ocean" (Brazier 1978). A major part of the analysis utilized one-way analysis of variance to test for effects of platform type (airplane vs. research vessel vs. tuna vessel), time of year, and geographic area (among other factors) on estimates of mean school size. Problems with the data and problems with potential but un-studied interactions between factors apparently rendered the report unusable. Problems with the data included, for example, statistically different estimates of school sizes made by tuna boat crew, tuna boat observers, research vessel observers, and aerial survey observers. The results were not particularly useful. Brazier's report is rarely referenced in later documents although a similar analysis of variance approach was used subsequently by Clark (1984) and Parks (1985), and was extended by Holt and Powers (1982) to a multi-way analysis.

A second report (Brazier and Danneberg 1978), while not using TVOD *per se*, includes an intriguing analysis of interviews with tuna fishermen and with fisheries observers. The report compares the two groups' impressions of dolphin school sizes associated with purse-seine fishing. Individuals had very different opinions about the distribution of schools sizes but in general the 5 tuna fishermen interviewed judged the average school size to be more than twice as high as the average school size estimated by the 15 members of the non-fishing group (1270 v. 590, pg. 28) with estimates of maximum size being 18,000 and 6,900 dolphin, respectively. The report also presents anecdotal evidence that purse-seine fishing may have led in recent years to a decrease in school sizes and to greater difficulty in capturing schools, but no strong quantitative evidence is presented. Again, the report apparently provided little information directly useful for stock assessment and has been referred to only rarely.

1979: Second Major Research Survey; Second Status of Stocks Workshop (SOPS #2)

The second major research survey combining aerial and research vessel platforms was conducted from January through April 1979. Unlike the survey in 1977, this one did not include explicitly tuna vessels in the experimental design. A significant innovation during this survey was aerial photography of schools to validate observer's visual estimates of school size. In addition, this survey included an area of overlap (a "calibration area") surveyed by all three platforms (the airplane and each of the two survey ships). The calibration area was included in the design so that the efficiency of each platform could be assessed relative to each of the others.

Results from the survey, discussions of papers reviewed during four workshops held between 1977 and 1979, and the resulting population estimates are described in a report submitted by Holt and Powers (1979) to the second Status of Porpoise Stocks workshop (SOPS #2) held August 27-31, 1979 at the SWFC. As in 1976, workshop participants were asked to produce estimates, for each stock involved in the fishery, of 1) existing population size, 2) the relationship between this existing stock and OSP, and 3) the impact on existing stocks of various levels of mortality. Additionally, workshop participants were asked to determine if other more feasible management criteria should be adopted. The report from this workshop appeared in November 1979 (Smith 1979).

This second workshop obviously benefited from the three additional years of data collection since the first Status of Porpoise Stocks assessment (SOPS #1). Considerable attention had been given during the intervening years to improving line transect methods for estimating abundance of dolphins (e.g., Holt and Powers 1982).

Also, the problem of determining the lower bound for OSP was reconsidered. This lower bound was assumed to be each stock's maximum net productivity level (MNPL) but workshop participants redefined the population level at which MNPL is assumed to pertain. The participants felt that the lower bound (MNPL) adopted in 1976 (50%) was probably too low for dolphins, as MNPL tends to exceed 50% in other large, long-lived mammals. They opted instead for a level of 60-85% (Smith 1979).

The upper level for OSP for each species was, as in 1976, taken to be the pre-exploitation population level. These levels were calculated using the same recursive formula employed in 1976. But the new estimates incorporated the additional data on kill and reproductive parameters collected during the intervening years and used a new density-dependent formula for recruitment rate. Several different sets of values were used to estimate pre-exploitation population levels.

Because the estimates of current (1979) population levels were much lower than the levels estimated in the 1976 assessment, the 1979 report lists in detail the differences in estimation methods between the two assessments and stresses that the differences are due mostly to these differences in method rather than to any dramatic change in population levels. These differences are discussed below.

1) School density: In 1976 school density was estimated for some species using only TVOD; for other species, estimates of school density were based on both TVOD and RSOD. In 1979, TVOD were not used at all to estimate school density; only RSOD (aerial and research vessel) were used for the new estimates. School density was estimated separately for each of three geographical areas: an inshore area surveyed by airplane and two offshore areas (northern and southern) surveyed by two research ships. The ship and aerial surveys overlapped in a common "calibration area", where density was estimated from both sets of data. Line transect methods were used to estimate school density in the inshore area. Line transect methods were judged inappropriate for analyzing the ship data from the two offshore areas because of possible evasive movements by dolphin schools reacting to the survey ships. Density in these offshore areas was estimated instead by another version of the ratio method; "multiplying the density estimated from the aerial survey data in the calibration area by the ratio of schools sighted per mile searched in the outside area to schools sighted per mile searched in the calibration area. The final density estimate for the outside areas was the average over the two vessels, weighted by miles searched" (Smith 1979).

Line transect analysis was used during both 1976 and 1979 to derive the estimates of schools density from sightings data, but different functions were used in 1979 than in 1976. In 1976, Smith used the negative exponential function to fit the sighting frequencies. Subsequent investigations showed that Fourier series functions provided a better fit to sightings data, so Holt used this other function in his analyses in 1979.

2) School size: The assessment in 1976 used estimates from TVOD, uncorrected for the possibility that larger schools may be easier to see and so may be sighted more often. This would cause an upward bias in estimated mean school size. In 1979, two estimates of mean school size were generated, both using aerial and research survey data rather than TVOD, and both corrected for bias associated with sighting larger schools more easily. The first estimate was "unadjusted" for the possibility that "species composition in the aerial survey data may not represent the true composition due to problems with species identification" (Smith 1979). The second estimate adjusts for this, using as a ratio correction factor the average school sizes from TVOD 1977 - 1979 divided by average school size from the 1979 aerial survey. The adjusted estimate was slightly higher than the unadjusted (230 versus 220 dolphins per school). Because neither estimate could be agreed superior, population levels were estimated for each.

3) <u>Species proportions:</u> In 1976, species proportions of sighted schools were estimated from TVOD, but were not corrected for the fact that tuna vessels apparently look for and therefore sight more often some species than others (e.g., spotters more often, common dolphins less often). In 1979, estimates of species proportions were derived in 2 steps, in an attempt to solve this problem. TVOD were used only in the second step.

In the first step, aerial and research survey data were used to estimate the proportion of all observed schools that were target schools. Target schools are schools with dolphins that contain at least one of the species most strongly affected by the purse-seine fishery; spotted dolphin (*Stenella attenuata*), spinner dolphin (*Stenella longirostris*), striped dolphin or streaker (*Stenella coeruleoalba*), and common dolphin (*Delphinus delphis*).

In the second step TVOD were pooled with the research vessel survey data to estimate species proportions within each target school. Aerial survey data were not used in this second step because the species identifications from the aerial survey were questionable. TVOD were used in addition to the research vessel data because survey data were sparse in some of the geographic statistical areas. This combining of data types was carried out under the assumption that species composition of sighted target schools did not differ between research and tuna vessels.

Two different methods were used to estimate species proportions in target schools. The simplest method used the ratio, for each area k, of the <u>number</u> (n_{ik}) of individuals in species (i) divided by the total <u>number</u> of individuals of all species observed in that area (n_k).

The second estimate was developed to account for the possibility that individuals of some species may be more or less easily sighted than others. For example, some species habitually form larger, more easily-seen schools than other species (i.e., spotted dolphin schools tend to be much larger than schools of striped dolphin). Also, some species are preferentially sought out or ignored by tuna fishermen (e.g., spotted dolphin are sought, striped dolphin are avoided). This second estimate was the ratio for each geographic subarea(k), of estimated <u>density</u> (number per area) of individuals of species(i) to estimated <u>density</u> of all species in that area, where both estimates of density were based on research vessel data and TVOD combined (Smith 1979).

4) <u>Area inhabited:</u> In 1976, density estimates were extrapolated without adjustment to areas with no survey coverage. In 1979, aerial survey data were extrapolated to outer areas by using adjustment factors based on (sparse) research vessel survey coverage. Estimates for stocks were derived from estimates for species by assuming stock size in each subarea(k) was proportional to the "ratio of the area occupied by the jth stock

of species(i) to the area occupied by all stocks of species(i) in subarea(k)" (Smith 1979, pg. 16).

5) Total range: In 1976, abundances were estimated twice, once for each of two different assumptions about inhabited range. In 1979, only one geographic range was used for each stock. These stock-specific ranges were based on geographic differences in morphology and on TVOD and research vessel surveys conducted from 1976 through 1979. The ranges in 1979 were very similar to the larger ranges used in 1976.

6) Stock or population sizes: Dolphin abundances were then estimated as the product of average school size, density of schools, and area inhabited. Two estimates were generated for each stock; one using the simpler, "unadjusted" formulae for school size and species proportions, the other using both of the "adjusted" formulae. The differences in estimated stock sizes were substantial, and were not consistent. For example, adjusted estimates for offshore spotter dolphin (82% of all spotters) were 13% lower than unadjusted estimates, but adjusted estimates for common dolphin were 230 to 250% higher than unadjusted estimates (Table 7 in Smith 1979).

As in 1976, the remainder of the workshop report is devoted to estimates of current and historical kill, and to comparisons of estimated current and historical population levels. Details of the calculations do not appear in the report itself, but in the working papers prepared prior to the workshop. A list of these papers appears in an appendix of the working report (Smith 1979).

The stock assessment produced in 1979 was followed, as had been the assessment in 1976, by a series of court hearings resulting from legal challenges brought against the assessments. Eventually, the administrative law judge recommended and NMFS used in their analyses estimates of school size based on TVOD, estimates of school density based on RSOD and estimates of species proportions based on the combined sets of TVOD and RSOD.

1980: Aerial Photography from the *Gina Anne*

The only report appearing in 1980 relevant to estimation of dolphin abundance was a study of school size estimates derived from aerial photographs taken during tuna-dolphin capture operations for the chartered purse-seiner *Gina Anne* (Perryman 1980).

1981: No New Developments

1982: Holt and Powers

In 1982, Holt and Powers (1982) published a revision of their workshop paper (Holt and Powers 1979). Specifics of this revision are discussed below. The only other reports appearing that year related to estimating dolphin abundance were 1) a trip report describing the aerial survey conducted January 22-April 25, 1979 (Jackson 1980) and 2) a bibliography of marine mammal research at the SWFC (Rivers 1982). No new analyses of TVOD appeared.

Holt and Power's (1982) revision describes in detail the assumptions required for line transect estimation of density, and how these assumptions were satisfied (or not) in the dolphin survey for both the aerial and research vessel survey platforms.

A significant section of this report discusses in detail NMFS researchers growing concern with the differences in encounter rates and estimates of school size by a) observers vs. crew aboard the same tuna vessel, and b) observers on tuna vessels vs. observers on research vessels. Observers on tuna vessels consistently reported sighting more schools and smaller schools than reported by crew members. Except for 1974, when both crew and observers saw about 600 schools, tuna-vessel observers saw each year 15% to 165% more schools than the crew members (observers reporting 600 to 4300 schools/year, crew reporting 550 to 3800). School sizes reported by observers were each year 30% to 50% lower than school sizes reported by crew members (observer estimates 450 to 900, crew estimates 900 to 1200). In addition, both sets of estimates from tuna vessels (observers and crew members) are much larger than estimates of mean school size based on data collected during research vessel surveys. Comparing TVOD and RSOD estimates of mean school size for target species in 1977 and 1979, Holt and Powers (1982) found TVOD estimates of 500 to 800 dolphins/school, versus RSOD estimates of 115 to 190 dolphins/school (Table 17 in Holt and Powers 1982).

Estimates from aircraft were not significantly different from the research vessel estimates. Because the aircraft estimates had been validated by aerial photographs, only the estimates of mean school size from the aerial survey were used in the final estimates of abundance.

Also relevant to TVOD is the multi-way analysis of variance used by Holt and Powers (1982) to test for effects of geographic area (4 areas), quarter of the year, and the interaction of area and quarter, on estimates of mean school size derived from TVOD for 1974 through 1979. They tested separately estimates from NMFS observers and estimates from crew members. Neither of the main effects (year or area) were significant, but the interaction term (year X area) was significant for both NMFS data and crew data. As usual, it could not be determined from that analysis whether the effects reflected real differences in mean school size, or simply artifacts of data collection.

As in Holt and Power's earlier report (1979), TVOD was again used in the second stage of estimating species proportions. The first stage, determining the fraction of sighted dolphins that belong to the "target" species, used only data from aerial and research vessel surveys. The second stage, determining the average species composition of target schools, did not use aerial survey data because the data were relatively few and not all species were equally easy to identify. Three different estimators were used for stage two, based on three different data sets; 1) 1979 RSOD, all areas pooled, and 2) 1977 and 1979 RSOD, pooled over both years and all areas, combined with 3) TVOD from 1977 through 1979 stratified by area.

These three alternatives were chosen because of unresolvable doubts about whether 1) RSOD provided adequate coverage of all areas, 2) observed species proportions (proportions of total abundance apportioned to each species) might be artifacts of unequal searching effort in different areas, and 3) observed species proportions in TVOD might not reflect true proportions, because tuna vessels may selectively ignore (and so not report) those species and school sizes not likely to carry tuna.

Holt and Powers (1982) then combined the various estimates of school density, mean school size, species proportions, and geographic range to produce several alternative estimates of population size for the four major species of dolphins involved in the purse-seine fishery. The differences between TVOD- and RSOD-based estimates of school size and species proportions produced dramatic differences in estimates of abundance.

Estimates based on RSOD were relatively similar in 1977 and 1979, but were considerably lower than estimates based on pooled RSOD and TVOD. Estimates based on TVOD were 54%, 25%, and 37% <u>higher</u> than RSOD for spotted, spinner, and common dolphins. In contrast, the TVOD-based estimate of striped dolphin abundance was 75% <u>lower</u> than abundance estimated from research vessels (Table 26 in Holt and Powers 1982). Problems in data collection and analysis contributing to these differences are discussed, but no one set of estimates is specifically identified as the most correct. An example of the unresolved problems is the difference in species proportions observed from research versus tuna vessels. Holt and Powers suggest, but could not show with existing data, that the differences might have resulted from the preferences of tuna fishermen for sighting schools of spotted, spinner and common dolphin, which tend to carry more tuna and to be easier to catch than striped dolphin.

Holt and Powers' (1982) estimates of abundance based on pooled TVOD and RSOD collected 1977 through 1979 are relatively similar to the "unadjusted" estimates for abundance in 1979 appearing in the 1979 assessment document (Table 7 in Smith 1979). No comparisons between these different estimates are made or discussed in Holt and Powers (1982), although comparisons are made between the 1980 assessments and those made in 1974 and 1976.

1983: Pre-SOPS Meetings Begin

In 1983, no new estimates of abundance were generated but two reports appeared describing an aerial survey experiment testing detection of schools on the aerial trackline (Holt 1983a) and a research vessel marine mammal survey conducted in the ETP, May 15-August 3, 1982 (Holt 1983b). The reports describe the events but do not present any analysis of the data. Results from the 1979 assessments for spotted, spinner and common dolphins appeared in Fishery Bulletin (Smith 1983).

Between January 1983 and March 1984, 10 preliminary workshops (Pre-SOPS panel meetings) were held at SWFC in anticipation of a 3rd stock assessment workshop to be held in 1985 (Perrin 1984). Topics addressed by these meetings included 1) species ranges, 2) oceanographic variables, 3) age-specific reproductive rates, 4) population growth models, 5) school size and species proportions, 6) school density, 7) abundance estimates, and 8) incidental mortality. The purpose of the meetings was to have a panel of invited scientists review SWFC research results which might be used in a Draft Environmental Impact Statement for the tuna-porpoise fishery of 1986 and beyond.

At each meeting, the review panel discussed, evaluated, and suggested improvements for papers prepared previously by SWFC researchers. Most of these papers appear in the SWFC administrative report series. Several have been published subsequently in peer-reviewed scientific literature (see Literature Cited). Those papers relevant to estimation of current population levels will be described below in the order of their appearance in the series. Comments of the review panels are included where relevant.

Panel Meeting C-1: School size and species proportions (August 25-26, 1983)

Panel members were requested to prepare for the meeting by reading Holt and Powers (1982) assessment of dolphin abundance and Scott et al.'s (1983) manuscript discussing use of aerial photographs for estimating sizes of dolphin schools. Then during the meeting, participants reviewed four new papers. The papers presented and the panel's comments are summarized below.

1) <u>Species proportions</u> (Barlow and Holt 1984): Barlow and Holt estimated species proportions in various geographic areas from both research vessel sightings data and TVOD. They found large differences between the platforms in estimated proportions, as well as large differences between geographic areas, between 5° squares, and under different environmental sighting conditions.

This paper generated substantial discussion among reviewers, particularly about the authors' suggestion that TVOD not be used for estimating species proportions. Reviewers concluded that estimates from both platforms should be examined in additional detail (i.e., under better definitions of effort).

2) Observer effects (Cologne and Holt 1984): Sighting rates and estimates of species proportions made by research observers and former tuna vessel observers during 2 research vessel cruises were compared, and the effect of various sighting conditions (e.g. watch length, sea state) assessed. Research observers sighted and identified more marine mammals than did the former tuna vessel observers, but both types of observer made similar estimates of size school and species proportions.

This paper generated fewer comments. These were generally suggestions for modifications of data analysis or presentation. No major changes were proposed.

3) School size; analysis of variance of photographic and visual estimates (Clark 1984): An analysis of variance comparing aerial and visual estimates of 71 dolphin schools showed that 1) visual estimates of school size estimates were relatively accurate for schools up to about 200 animals, 2) visual estimates of school size were too low for large schools (on average, about one-half the true size), 3) individual observers differed greatly and inconsistently in their ability to correctly estimate school size. Some tended to over-estimate, others to underestimate. No single correction factor could be defined that would be appropriate for all observers.

No substantial comments were offered on this paper, other than that "the basic problem of estimating schools size remains unsolved".

4) School size; sighting effects on estimates (Parks): No results were presented because the data sets were too large for available statistics packages. The analysis would have used TVOD.

The panel made a few methodological suggestions.

Panel Meeting C-2: School density (December 6-10, 1983)

Meeting participants were asked to review in advance Hammond and Laake's (1983) estimates of trends in abundance of *Stenella* and *Delphinus*, and Polachek's (1983a) investigation of relationships in TVOD between search effort, tuna catches, and dolphin sightings.

1) Reaction of schools to survey vessel (Hewitt 1985): Helicopter tracking of schools in the vicinity of a research vessel showed that only 1 of 13 schools reacted to the vessel before being sighted by the observers on board ship; 4 other schools reacted after being sighted. Shipboard observers saw only 13 of the 19 schools tracked by helicopter. This is similar to Au and Perryman's (1982) results from an earlier study on the

research vessel *Surveyor*. Au and Perryman (1982) found that 8 dolphin schools appeared to react to the vessel, but that most schools did not react before being sighted by the observers on the research vessel.

Reviewers recommended more detailed descriptions of methods, more discussion of implications of results, and more comparisons between this study and others.

2) Testing the validity of line transect theory to estimate abundance of dolphin schools (Holt 1984a): Sea state and observer performance did not significantly affect estimates of school density derived from data collected during an experimental aerial survey in a localized area. Sun glare did affect significantly estimates of school size.

Reviewers made several suggestions for reanalysis of the data, so no final conclusion was possible.

3) School size; effects of sighting factors (Parks, second review of paper): Reviewers suggested many changes to the structure of the analysis and reserved final comments until the study was redone.

4) Estimation of density of dolphin schools in the ETP Ocean using line transect methods (Holt 1984b): School density was estimated for "inshore" areas from aerial survey data collected during 1977 and 1979, and for "offshore" areas from RSOD collected during 1977, 1979, 1980, 1982, and 1983. Aerial survey data were analyzed directly by line transect methods. RSOD data required "smearing" before use in line transect analysis (Butterworth 1982). In a second approach to using ship survey data, RSOD were "corrected" for biases by comparison with aerial data. Estimated density inshore was 3.6 schools/1000 square nautical miles. Estimated density offshore ranged from 1.5 to 2.4 schools/1000 square nautical miles, depending on the estimation method used.

Reviewers advised that some reanalysis be done, particularly with respect to the potential effects of increased sea state and sun glare on estimates of density offshore.

5) Observer effects on shipboard surveys (Cologne and Holt 1984): This had been reviewed previously in Meeting #1. Suggestions had been incorporated, and reviewers were satisfied with results.

6) Distribution of search effort by purse-seiners 1977-1980 (Polachek 1983a): Within each year, search effort by purse-seiners is concentrated in a small fraction of the total area inhabited by dolphins. Even within this proportionally small area, search effort is highly concentrated in some small subareas but very diffuse in close-by neighboring subareas. Specific areas of concentration shifted from year to year, and consistently from season to season within years. North of the

equator, search effort was concentrated nearshore in summer and fall but was more diffuse and somewhat heavier offshore in the spring and summer. Effort south of the equator was relatively sparse and occurred mostly in fall and winter.

Reviewers noted that although the paper demonstrated that search effort by tuna purse seiners in the ETP was highly non-random even on small scales (less than 2 degrees square), it did NOT address the question of whether the effort was concentrated in areas of high or low density of dolphins.

1984: Panel Meetings Continue; MOPS Planning Begins

Panel Meeting C-3: Abundance (March 1-2, 1984)

There were no background documents for this meeting. Panel members reviewed three revised manuscripts and three new manuscripts. Results and comments are summarized below.

Revised manuscripts

1) Testing the validity of line transect theory to estimate density of dolphin schools (Holt 1984a): New stratifications by area and sea state showed no significant effects. Panel members could not agree a single analysis, but suggested another stratification scheme for sea state. Panel members discussed but also could not agree upon the significance of the problem that sea state and geographic area might be confounded, with higher sea states occurring more often offshore.

2) Estimating density of dolphin schools in the ETP using line transect theory (Holt 1984b): Reviewers suggested re-calculating aerial survey detection rates again, after stratifying by sea state and sun glare. They also suggested that density estimates in the inshore area should be calibrated using only data collected inside the calibration area.

3) Effects of various sighting factors on estimates of school size (Parks): Revision incomplete.

New manuscripts

1) Analysis of the relationship between distribution of search effort, tuna catches, and dolphin sightings within individual purse-seines cruises (Polachek 1983a): Search effort did not follow a Poisson distribution (i.e., it was not random) during 80% of 35 cruises by U.S. purse-seiners in 1979. Rather, tuna vessels tended to concentrate their searching effort in clusters of sets.

Results suggested that density of dolphins (assuming density is reflected in encounter rates) and catches of tuna were higher within clusters than between clusters. Encounter rates (total number of sightings divided by the total distance searched) tended to be much higher within clusters of dolphin sets than in clusters of non-dolphin sets or during searching between clusters (Table VI-7, Polachek 1983). For example, the mean encounter rate was 2.46 schools of spotted dolphin/100 miles searched (s.e. = 0.21; n = 30 cruises) in clusters where 75-100% of the sets were made on dolphins. The mean encounter rate was only 0.1 (s.e. = 0.05; n = 27) in clusters where 0-25 % of the sets were made on dolphins; between clusters, the rate was 0.50 (s.e.= 0.05; n = 35). Tuna catches were also significantly higher within than between clusters ($P < 0.05$; nonparametric sign test, Snedecor and Cochran 1983; from Table VI-8, Polachek 1983).

Reviewers suggested that alternative tests be investigated for the presence or absences of a Poisson distribution.

2) <u>Estimates of abundance of dolphin stocks taken incidentally in ETP</u> (Holt 1985a): Abundance estimates are presented for 19 stocks of 5 species. Estimates are presented with and without adjustments for both sea state and sun glare. School density and proportions of sighted schools that contained target species were estimated from aerial and research vessel survey data. Species proportions in target schools were estimated for 5° squares using RSOD and TVOD. Species proportions were estimated twice; once weighted by encounter rate, once not. Mean school size was estimated from aerial surveys, research surveys, and TVOD. Various estimates of abundance are presented for various sets of parameter values. Recommended estimates used unadjusted estimates of density, unweighted estimates of species proportions, and school sizes based only on RSOD.

Holt compared his results with Hammond and Laake's estimates of abundance derived only from TVOD collected 1977-1981. Holt's estimates for the most heavily fished species (spotted dolphins) were somewhat lower (2.7-3.0 vs. 2.2-5.1 million animals) and estimates of the species fished less heavily were higher than Hammond and Laake's (0.38-0.41 vs 0.11-0.34 million animals, eastern spinner dolphins; 0.97-0.98 vs 0.28-0.68 million animals, whitebelly spinner dolphins). These results are consistent with the suggestion that tuna vessels actively seek to encounter and perhaps record preferentially encounters with the more preferred species, to the neglect of others (e.g., Barlow and Holt 1984).

Reviewers discussed the unresolved problems of 1) accounting properly for effects of sea state and sun glare, 2) differences between research platforms and tuna vessels in proportion of sighted schools containing target species, and 3) significance of decreasing trend in estimated school sizes derived from TVOD, seen in Hammond and Laake's analyses.

They also suggested using only aerial survey data for estimates of school size, if significant differences are found between estimates from research vessels and estimates from aircraft. The reviewers also suggested other methods of segregating "best" estimates from "alternative" estimates.

3) Encounter rates with schools of spotted dolphin in the ETP (Polachek, 1983b): There was no clear relationship between search effort and encounter rate. Encounter rates in specific areas were not constant year to year. Encounter rates were not significantly correlated with either school size or sighting distance. Encounter rates varied with season, being lowest in late fall (last quarter of year). Rates in northern areas were 1.5 to 5.5 times greater than in southern areas. Encounter rates inshore were different than encounter rates offshore, but differences derived from research surveys were opposite to those derived from TVOD. Research surveys found lower rates offshore: tuna vessels found lower rates inshore.

When asked by the panel whether encounter rates could be used as indices of relative density, Polachek expressed strong reservations, citing reasons listed on pages 43 - 48 in his MS. Reviewers also suggested that encounter rates be compared to estimates of density or abundance.

Other business, Panel Meeting #3

During this meeting, Barlow presented further data (drawn from Holt's and Polachek's data) showing differences in encounter rates of various species sighted from either research vessels or tuna vessels (Perrin 1984). These differences produced strong differences in estimates of species proportions based on these encounters. Encounter rates (schools/1000 nautical miles^2) of spotted and spinner dolphins were relatively similar on both types of ship (6.6 on research ships vs. 6.8 on tuna vessels), but encounter rates for common and striped dolphin were quite different (2.1 vs. 0.9; 3.0 vs. 0.4).

Several of these "pre-SOPS" papers appeared subsequently in revised form as SWFC Administrative Reports (i.e., Clark 1984, Barlow and Holt 1984, Cologne and Holt 1984, Holt 1984a, Holt 1984b, Parks 1985, Holt 1985a, 1985b), as papers published in peer-reviewed journals (Hewitt 1985, Holt 1987a, 1987b, Polachek 1987) or as dissertations (Polachek 1983c).

[MOPS Planning Begins]

Having completed the panel meetings, NMFS was ready in 1984 to conduct its third Status of Porpoise Stocks workshop (SOPS #3). But these plans were changed following an amendment to the Marine Mammal Protection Act in 1984. This amendment charged NMFS with responsibility for monitoring trends in relative abundance.

The first planning meeting was held in October 1984. Technical review meetings were held in November 1984 and February 1985 (letter from Barrett to Angelovic; February 25, 1985).

At the first planning meeting in 1984, NMFS elected to continue their historical emphasis on research vessel surveys as the basis for stock assessment. Aerial surveys were considered less than optimal because survey planes with suitable downward visibility couldn't carry sufficient fuel to survey the entire area. TVOD were considered less promising than RSOD for at least three reasons: 1) the suite of unresolved problems in interpreting TVOD, 2) changes in patterns of fishing effort year to year potentially compromising any plan for annually consistent surveys, and 3) the observer program could be eliminated at any time by court action.

Although TVOD were not considered further in developing the research vessel monitoring survey, several participants in the first technical review meeting (November 13, 1984), including representatives from the Marine Mammal Commission and from the tuna industry (Report of 13 Nov. workshop, pg. 7) felt strongly that further effort should be expended to determine whether or not TVOD could be used to detect trends in abundance.

1985: MOPS Planning Continues; Technical Review Meeting #2; TVOD Planning Workshop

In response to this interest, the second technical review meeting included a one-day workshop (February 7, 1985) to review possibilities for incorporating TVOD into the monitoring program. Workshop participants reviewed and discussed three papers. One described the results of an experiment conducted aboard a chartered tuna vessel (Allen et al. 1980), the other two estimated relative abundance of dolphin from analyses of TVOD (Hammond and Laake 1983, Polachek 1983c). These three papers and reviewers comments are discussed in turn below.

During the charter experiment, school sizes were estimated by tuna vessel crew, scientific observers, aerial counts, aerial photographs, and counts made during backdown (Allen et al. 1980). No consistent biases were apparent from comparisons of the various estimates. Allen et al. (1980) had concluded that "accurate estimates of school size could be made from aerial photographs from a helicopter and a tuna vessel, at least one operating in an experimental mode and given the school sizes encountered during the experiment".

The paper evoked a discussion of observed trends in school size estimates derived from TVOD. Several sources of artifact, such as changes in instructions to observers that might have led to the observed decrease in average school size estimated from TVOD (Hammond and Laake 1983) were discussed by panel members but no conclusions were reached or analyses suggested to resolve the problem. One objection to the explanation based on change in instructions was that the decrease occurred for some schools (e.g., spotted dolphin) but not others (i.e., common dolphin). If the decrease was simply due to change in instructions, one would expect average school sizes to decrease for all species, not just one or two (Holt, pers. comm).

Although both Hammond and Laake (1983) and Polachek (1983c) were interested in TVOD as a basis for estimating dolphin abundance, the two studies are quite different in focus and in analyses performed. Rather than attempting to resolve the apparently intractable problems of line transect analysis, Polachek (1983c) developed a different approach, analogous to catch-per-unit-effort analysis of fishery data. His analyses are based entirely on searching effort of individual tuna vessels and concomitant encounter rates with schools of marine mammals. Citing unresolved biases in existing estimates of school size and implicitly assuming that increases or decreases in population abundance will be reflected in increases or decreases in number of schools, rather than in numbers of individuals per school, Polachek (1983c) did not expand his analysis of encounter rates to estimates of numbers of individuals.

In six consecutive chapters of his doctoral dissertation, Polachek progresses from 1) a history of TVOD, the tuna purse-seine fishery, and previous estimates of dolphin abundance, through analyses of 2) the distribution of search effort by tuna vessels, 3) the relationship between search effort, catches of tuna and dolphin sightings during individual cruises, 4) factors affecting encounter rates with spotted dolphin, 5) encounter rates with spotted dolphin, to 6) estimates of relative abundance for 9 types of cetacean schools, in relation to spatial distributions and characteristics of the physical environment. The chapters on search effort, relationships between search effort, tuna catches and encounter rates, and estimated encounter rates of spotted dolphin schools had been presented during the pre-SOPS review, but had not been used directly in Holt and Powers' (1982) estimates of abundance.

Polachek concluded from his analyses that TVOD provided unique opportunities to study the spatial patterns of tuna vessel search effort. In particular, he demonstrated that tuna vessel search effort is significantly non-random even within 2 degree squares. This is important because if the spatial patterns of effort could be demonstrated random at some spatial level then the fundamental assumption required for line transect analysis, that search effort is random with respect to the distribution of sighted objects, would be satisfied. Other assumptions would remain to be satisfied, but those are more tractable that the assumption of random search. Polachek noted that this problem of non-randomness persisting even at small spatial scales may represent the fundamental problem with using TVOD for line transect analysis. Even with the huge number of TVOD there are often too few data per square for meaningful analyses, when the data must be stratified into areas smaller than 2 degree squares.

In addition to the demonstrated non-random nature of sighting effort, the many other unresolved biases and limitations in TVOD led Polachek again to express strong reservations about interpreting trends in encounter rates as accurate reflections of trends in population abundance.

The review panel was non-committal about Polachek's study, making only several suggestions for possible factors that might have affected the results. The only further work suggested specifically was a similar analysis from earlier years (1962 through 1972) when populations should have been changing most quickly (Report of Meeting, February 1985).

The discussion of Hammond and Laake's paper concentrated on defining advantages and disadvantages of using TVOD to monitor populations of dolphins in the ETP, and identifying studies that could be done to assess the utility of TVOD for this purpose. Specific suggestions included 1) an analysis of existing estimates of school size and factors that might have affected these estimates, 2) comparison of school size estimates from areas searched simultaneously by both research and tuna vessels, 3) experimental tests of various factor's influence on school size estimates, 4) devising methods to test the accuracy of TVOD, 5) designing experiments to photograph schools from tuna vessel helicopters, and 6) continuing to collect biological specimens.

To consider the problem further, researchers at SWFC convened on 13 November 1985 a planning workshop on uses of TVOD to index trends in abundance of ETP dolphins (Reilly 1987, Appendix 2). TVOD analysis was now identified as one of three major activities comprising the NMFS monitoring program. The other two were the annual research vessel sighting surveys, and monitoring of biological indicators via specimens from the industry.

Participants at the November 1985 workshop were asked to 1) "clarify workshop objectives,..,2) define some unequivocal criteria to judge progress,.., and 3) identify the major parts of the problem of using TVOD to index dolphin abundance" (Reilly 1987, Appendix 1).

As background, participants were asked to review 1) several methods of abundance estimation (Smith 1975, Holt and Powers 1982, Hammond and Laake 1983, Polachek 1983c), 2) estimates of species proportions (Barlow 1984, Barlow and Holt 1984), 3) IATTC research in progress, 4) a preliminary study on space-time scales of search effort by individual tuna vessels, and 5) relationships between dolphin distributions and oceanographic features.

The panel members agreed to re-word the program objective as "Determine if, and how, tuna vessel observer data and ancillary information can be used to monitor (with acceptable precision and accuracy) trends in ETP dolphin abundance".

The panel agreed unanimously that criteria to determine whether the objective had been met must include measures of accuracy and precision. Other suggestions were offered, but no clear consensus was reached on other specific criteria.

Following the discussion of criteria, the group identified 42 potentially significant research topics that should be considered in designing a program to evaluate uses of TVOD for abundance estimation. These topics, sorted into 8 categories included:

1) data stratification and searching processes
2) line transect methods
3) school size estimation
4) stock identification
5) method development and comparisons
6) inter-method and inter-platform calibration
7) observer effects and data collection
8) economics.

The panel then ranked the topics, giving highest priority to 1a) extending Hammond and Laake's line transect analysis to include subsequent years, more rigorous tests for violation of assumptions and more detailed analysis of school size, and 1b) investigating and evaluating data stratification procedures, including space-time variations in searching processes, fishery operations, and environmental parameters.

Second highest priority was given to 2a) comparing research and tuna vessel data collected simultaneously, 2b) randomizing TVOD by subsampling, and 2c) testing for correlations between environmental variables and TVOD.

IATTC announced plans to concentrate research efforts on topics 1a, 1b, and 2b. SWFC announced plans to concentrate research efforts on topics 2a and 2c. Panel members felt that no further workshops were necessary until progress had been made on the prioritized topics.

Following this workshop in November 1985, SWFC staff developed for TVOD a "Research Plan for FY-1987 and beyond" (Reilly 1987). Based primarily on the research topics and categories discussed during the November workshop, the plan included four basic elements;

1) define searching effort
2) model development
3) calibration of TVOD with known platforms
4) biological affects and assessment indices.

Element 1) (search effort) was included on the assumption that understanding exactly how tuna fishermen search for tuna (and sometimes dolphins) is fundamental to evaluating apparent biases in TVOD (Edwards 1989). Element 2) (models) encompasses three types of models, a) line transect models, because "it was the consensus of the Observer Data Workshop that line transect models held the most promise for utilizing TVOD to index dolphin abundance", and b) "non-line transect models", e.g., mark-recapture, CPUE (catch-per-unit-effort) and c) new types of models. One of the new models in development is a simulation model of the TVOD collection process (TOPS: Tuna-vessel Observer Program Simulator). The model simulates the movements of tuna-dolphin aggregations and tuna vessels in a 1200 x 1200 nautical mile area representing a central portion of the area exploited by the eastern tropical Pacific tuna purse-seine fishery. The model is used for testing current and proposed analyses of TVOD for trends in dolphin abundance (Edwards and Kleiber 1989, Kleiber and Edwards 1989).

Element 3) is fundamentally necessary to evaluate apparent biases in TVOD. Without controlled experiments or at least some sort of replication or comparisons between vessels, it is impossible to determine the relationship between indices derived from TVOD and the true status of dolphin stocks. Element 4) is included because population dynamics theory predicts, and populations in some real systems show, that life history parameters may change in response to predation pressure (i.e., incidental mortality of dolphins during fishing operations). This element will attempt to determine whether fishing (predation) pressure from the purse-seiners has produced changes in life history parameters of dolphins stocks in the ETP.

Subsequent to submitting this plan, a new program ("Fishery Dependent Assessment Program" (FDAP)) was organized at SWFC. The program began in April 1987 with two major foci: 1) determining relationships between dolphin distribution and characteristics of the physical environment, and 2) evaluation of existing techniques (e.g., CPUE), and development of new methods (e.g., fishery simulation modeling) for assessing the utility of TVOD for abundance estimation.

Although FDAP was organized specifically to investigate uses of TVOD, not all TVOD studies currently being conducted at SWFC are contained within the program. Calibration studies (platform comparisons) and studies to evaluate school size estimates (element 3, above) are currently contained within the program responsible for the research vessel monitoring surveys (the "Fishery Independent Assessment Program " (FIAP).

In addition to these two programs administered by the SWFC, a third major program is being conducted by the IATTC, focusing on continued refinement of methods for using line transect analysis of TVOD to detect trends in dolphin abundance in the ETP.

This section has described the history of NMFS/SWFC involvement in estimating abundance of dolphins affected by the tuna purse-seine fishery in the ETP. The next section describes the history of involvement by the other major agency concerned with the "tuna-dolphin problem", the IATTC.

IATTC RESEARCH PROGRAM

General History

The IATTC, established in 1950 by a treaty between the United States and Costa Rica, is responsible for "gathering and interpreting information to facilitate maintaining, at a level which will permit the maximum sustainable catches, populations of yellowfin and other kinds of fishes taken by vessels fishing for tropical tunas in the eastern tropical Pacific Ocean" (Joseph 1970). The major activity of the IATTC is collection and analysis of catch and effort statistics from the ETP tuna fishery. Since 1979, an additional activity has been study of the dolphin populations affected by the fishery. The organization's budget is contributed by member nations. Each nation's required contribution is computed relative to the U.S. at a value of 100, as a function of tuna utilization by each nation. Traditionally, the majority of financial support has been supplied by the United States.

Aware that the tuna-dolphin controversy and the United States Marine Mammal Protection Act of 1972 were having and would continue to have a strong influence on tuna fishing in the ETP, IATTC at its 32nd annual meeting in 1975 proposed developing a research program "to resolve the tuna-porpoise issue" (IATTC 1977). IATTC staff discussed several options for Commission involvement in the tuna-dolphin problem, and selected as the most appropriate objectives that: (1) "the Commission should strive to maintain a high level of tuna production" and (2) "also to maintain porpoise stocks at or above levels that assure their survival in perpetuity", (3) "with every reasonable effort being made to avoid needless or careless killing of porpoise" ("minutes of Commission's 33rd meeting", quoted in background paper for 34th meeting).

In 1978 the Commission instituted a research program that continues to the present. The objectives of the program in 1978 were to: (1) monitor abundance and mortality of dolphins, using TVOD, (2) conduct aerial surveys and porpoise tagging, (3) analyze indices of abundance, and (4) conduct gear and behavioral research (IATTC Annual Report 1978).

By 1985, these objectives had been revised somewhat to include: (1) population assessment, including the estimation of dolphin abundance, incidental mortality rates, and other life history parameters, (2) methods of reducing dolphin mortality, including development of new or improved fishing technology and the study of dolphin behavior, and (3) interactions between tuna and dolphins.

IATTC'S primary emphasis has been always on the first objective, population assessment. In support of this, IATTC initiated in 1979 an observer program very similar to that conducted by NMFS. The major differences between the NMFS and

IATTC programs were and continue to be that: (1) NMFS observers collect some data that are not collected by IATTC, and vice versa, and (2) NMFS observers are sent exclusively on U.S. vessels while IATTC observers monitor the international fleet, which includes U.S. vessels. IATTC observers thus monitor both U.S. vessels and those non-U.S. vessels which elect voluntarily to participate in the observer program.

Neither membership in IATTC nor participation in the observer program have been constant. The original signatories were the U. S. and Costa Rica in 1950. Other members have included Panama, Ecuador, Mexico, Canada, Japan, France, and Nicaragua. Ecuador left in 1968, Mexico in 1978, Costa Rica in 1979, and Canada in 1984. As of 1986, membership included only the U.S., Panama, Japan, France, and Nicaragua (IATTC Annual Report 1986). The observer program is not limited to member countries, however. Although Mexico is no longer a member, it joined the observer program in 1986. During the same year, other non-member participants included Costa Rica, Ecuador, Spain, Vanuatu, and Venezuela.

The major incentive for voluntary participation in the observer program by non-U.S. countries has been that U.S. law forbids importing tuna from countries which cannot document that the tuna were caught using methods conforming to U.S. regulations and standards for incidental kill of marine mammals or that the fishing was accomplished in such a manner that incidental mortality and serious injury of dolphins does not exceed that which results from U.S. fishing operations. This ruling (50 CFR Part 216) became effective January 1 1978. Nonetheless, some of the non-U.S. countries with the largest fleets have declined to participate during some years so that coverage of the non-U.S. fleet has generally been much lower than coverage of the U.S. fleet. During 1985 for example, 45% of the dolphin-fishing trips by U.S. vessels carried observers, but only 21% of the non-U.S. dolphin fishing trips included observers. This situation has improved since 1986 when Mexico, whose vessels now comprise over 30% of the total purse-seine fleet, voluntarily joined IATTC's observer program.

The chronology of tuna-dolphin research by the IATTC since 1979 can be found in the agency's Annual Reports. The only reference to research prior to 1979 appears briefly in a NMFS document produced in 1975 (Smith 1975). The following section summarizes research results as presented in Smith (1975) and in the series of IATTC Annual Reports.

1973: IATTC's First Estimates of Abundance

In 1973, IATTC researchers Joseph and Klawe (1973) produced the first estimate of absolute abundance (as opposed to trends) of dolphins in the ETP (all species combined). They derived the estimate from IATTC data on number of porpoise sets per days fishing (Smith 1975), making some assumptions about the number of porpoises captured per set. This estimation procedure was subject to the same problems as Smith's (1975) estimate of encounter rate, and has not been repeated since. Instead, IATTC has concentrated primarily on developing and refining line transect estimation procedures.

1979: IATTC Observer Program Begins

IATTC began training observers for its international program in 1978. The first group went to sea in 1979. IATTC's observer program continues to the present (1988). In addition to collecting data on dolphin mortality, IATTC instructs these observers to collect, as do the NMFS observers, the types of data that are required for line transect analysis (i.e., sighting distance and angles, school size, and species composition). Life history materials are also collected by observers for IATTC and NMFS.

IATTC researchers, aware of the potential problems with TVOD in line transect analysis, stated explicitly in early reports the assumptions and ways in which TVOD might violate these assumptions (see especially background paper, 38th Annual Meeting; assessment based on TVOD). The Commission has developed over time two general strategies to help alleviate these violations of assumptions: (1) stratifying TVOD in various ways prior to applying line transect analysis, and (2) discussing results in terms of relative differences in abundance year to year (i.e., in terms of trends) rather than absolute abundances.

The purpose of stratifying TVOD is to create subsets of data within which either search effort or dolphin distributions are more likely to be random with respect to each other than would be the case with unstratified data. The advantage of estimating trends rather than absolute abundances is that trend estimates can be accurate even if biases exist in the data, provided the biases are consistent over time. If biases in TVOD are consistent between different groups of data (e.g., from one area to the next, or from one year to the next) then estimates of abundance will be consistently biased but <u>differences</u> between these estimates will accurately reflect differences between population levels. Thus trends in abundance could be determined even if absolute abundances could not. The major practical problem with these two data treatments (stratifying and estimating trends) is determining quantitatively how effective the treatments have been. IATTC researchers, aware of this problem, have focused much effort on reducing it's severity but have found it difficult to quantify their effectiveness in the absence of a data set collected independently of the fishery itself to use as a control.

In 1979, IATTC researchers estimated density of spotted and spinner dolphin schools for the years 1974, 1975, 1977, and 1979 (IATTC Annual Report 1979). The data were stratified by areas defined on the basis of the type of fishing most prevalent in each area (i.e. school fish or porpoise). This stratification was chosen to reduce at least in part the problem of non-random search effort, although no quantitative evidence was presented to demonstrate whether or to what degree the stratification had been effective.

A "small scale computer simulation" of non-random search effort was described in the same report. Stratifying the data from this simulation in three different ways showed that "bias was much reduced," but no quantitative results were presented nor were any quantitative tests described that could show whether or not any given stratification scheme had truly randomized search effort relative to distribution of dolphins.

Also in 1979, IATTC researchers Hammond and Laake (1979) produced, in a background paper prior to the NMFS 1979 Status of Stocks Workshop (SOPS #2), estimates from NMFS TVOD of school density for 9 species of marine mammals for 1974 through part of 1979. Results were presented for unstratified data only, and cruise records from individual vessels were considered to be replicates. Potential biases in the estimates caused by (1) non-random searching effort and (2) movement by dolphin schools in response to approaching vessels were assumed to be consistent year to year. It was not possible, for any of the species, to determine whether trends in estimates of density reflected accurately true changes in abundance, or were simply artifacts of data collection and analysis. The authors concluded that stratification by area was an essential first step, but noted that TVOD for all but the major species were too few to allow any but the coarsest stratifications.

1980: Discussion of Line Transect Assumptions

In 1980, the IATTC Annual Report discussed in greater detail the results of extended and continued study on the use of TVOD and line transect analysis to estimate school density of ETP dolphins. Eight assumptions of line transect analysis are listed and discussed briefly with respect to TVOD.

Because dolphins were assumed to be non-randomly distributed, attention was directed instead to identifying stratifications of the data into subsets within which search effort might be random (IATTC Annual Report 1980). A test was proposed to assess whether search effort is non-random within any given stratification, based on the assumptions that (1) number of sightings (n) and search effort (F) are related by

$$[1] \qquad \ln(n) = \ln(a) + b \ln(F)$$

and (2) any significant divergence from unity of the slope coefficient (b) indicates that sighting success and effort are not proportional (i.e., not related linearly). Testing this relationship on TVOD stratified into 5°x5° squares, IATTC researchers found no significant departures from unity and concluded that "the fleet as a whole searches effectively at random and density can be estimated without bias in this respect."

This test was later criticized by Polachek (1983) for three reasons: (1) finding (b) much greater than 1 probably does indicate non-random search, but the reverse is not necessarily true, because (2) (b) can equal 1 even if the relationship between (f) and (n) is non-linear, e.g., if the relationship is sigmoid, and (3) as in other methods of catch analysis, sightings (n) are a function of effort (F) but conversely (F) is also a function of (n). Covariance (n,F) cannot be assumed zero. That is, the "independent" variable (F) is not in fact independent.

Equation (1) is the only quantitative test presented for satisfying any of the assumptions. The remainder of the report describes the ways in which TVOD probably violate each of the other assumptions of line transect analysis. Many of the potential or realized problems are discussed, but no quantitative solutions are presented.

1981: Trends in Abundance of Eastern Spinner Dolphins

By 1981, in response to unresolved concerns about violating various assumptions of LTA, emphasis had changed from estimation of absolute density or abundance to estimates of <u>trends</u> over time (IATTC Annual Report 1980; see also Laake 1981, Hammond 1981b, Allen 1981). IATTC researchers concentrated this year on estimating trends in abundance of eastern spinner (*Stenella longirostris*) dolphins. This stock was thought to have suffered the greatest incidental mortality and thus was the most likely to show strong trends in estimates of abundance. TVOD from 1977 through 1980 were stratified into 3 geographic areas on the basis of stock ranges. School density and abundance were estimated then for each year. The report states that the data used in the analysis are "subject to potential biases" but neither solutions nor tests for violations are discussed or presented. Results are discussed, but not evaluated.

School density did not show any trend, but a decreasing trend in mean school size generated a decreasing trend in estimates of abundance. Although at that time IATTC researchers felt that "there is no reason to believe that error in ... estimates of school size have changed in the area of investigation during the time period studies", subsequent reports suggest that this decrease in school size may have been caused by changes in training methods for observers (IATTC Annual Report 1982).

1982: Trends in Abundance of Spinner and potted dolphins; Smearing

In 1982, the analysis of TVOD for eastern spinner dolphins was continued and expanded to include northern and southern whitebelly spinners, and spotted dolphins. Special emphasis was given this year to using the technique of "smearing" (Butterworth 1982) to smooth the sightings data, and to estimating school density and abundances under three different stratification schemes (un-stratified, stratified by stock boundary, and stratified by fishing effort and fishing mode). The resulting trends are discussed, although evaluations of efficacy are not presented.

Several stocks showed a similar pattern of trends. These included: no apparent trend in estimates of school density, a decreasing trend in estimated average school size, and a resulting decrease in estimated abundance. Bias in school size estimates caused by changes in training methods are cited as a possible cause for the observed decrease in estimates of school size. The report also cites annual differences in weather patterns as a potential source of annual changes in bias, although no analyses are presented.

Different stratification schemes did lead to some differences in estimates of density and abundance. For example, no trend was found in estimates of abundance of eastern spinner dolphins when TVOD were stratified by stock, but a downward trend was apparent when TVOD were stratified by fishing mode and effort. The report does not present any criteria for selecting the "best" estimate or stratification scheme.

Also in 1982, analyses of percentage of cruise track length and percentage of area searched in each of the strata showed, in contrast to results presented in 1980, that searching effort is in fact concentrated in areas of apparent high density of dolphins. The earlier result is attributed to inadequate stratification.

1983: Trends in Abundance of Eastern Spinner Dolphins

In 1983, IATTC research on dolphin abundance was again focused on estimating trends in abundance of eastern spinner dolphins. Again the data were smeared and stratified by stock boundaries. Again school density and abundance were estimated for each year. Again no trend was evident in estimates of school density or abundance, for this stock-boundary stratification. Stratification by fishing mode and effort was not performed.

Also in 1983, Hammond and Laake (1983) published their analysis of TVOD from 1977 through 1981 for trends in estimates of density and abundance of spinner, spotted and common dolphins. They present estimates for unstratified, stock stratified, and fishing-mode stratified data. They discuss problems with school-size estimates and stress that "the results are only investigated for trends over time and not taken as indicators of actual abundance". Various potential sources of bias are discussed, but are not evaluated. Necessary assumptions are listed (e.g., it must be assumed when looking for annual trends in estimates that biases have not changed in magnitude from year to year) but ways to test whether the assumptions have been satisfied or violated are not presented.

1984: Report of Results from *Gina Anne* Experiment

The Annual Report of 1984 reiterated assumptions required for line transect analysis of TVOD and discussed again ways in which TVOD may violate these assumptions. One test of one assumption was discussed (probability of sighting a school was not correlated with school size in 1983). Suggestions were made for reducing some biases in TVOD (e.g., by smoothing the sighting angles and distances) but no methods were suggested to assess the accuracy of bias-reducing measures. Continuing problems with assessing the efficacy of various stratification schemes were mentioned (e.g., "further effort in defining an appropriate stratification method is needed") but solutions were not proffered.

In 1984, the results of a cooperative experiment with NMFS were published, in which dolphin school sizes were estimated by several different observers with different types of sighting experience, from shipboard, from helicopter, and during backdown, during a chartered cruise aboard the tuna purse-seiner *Gina Anne* in 1979. Photographic estimates were relatively precise (standard deviation of 6-8%; (n) unspecified). Observer estimates were fairly accurate for school sizes up to 200 animals, but most observers underestimated the size of large schools (10-30% at least, more likely 60-100% at the highest school sizes, data from Clark 1984). Also, observer biases, while consistent within estimates for each observer, were high for some observers and low for others. No overall correction could be derived that would apply consistently to all observers.

1985: Discussion of Problems with TVOD for Line Transect Analysis

In 1985, as in previous years, each of the major factors affecting line transect estimates were reiterated and discussed in the Commission's Annual Report. Discussions were more detailed than in earlier years, as a result of experience gained since inception of the program in 1979. Potential problems were categorized into type (i.e., accuracy or bias). Two types of bias were identified: (1) year-to-year fluctuations due to environmental changes (e.g., the El Nin~o of 1983), and (2) underlying trends independent of this annual variation (e.g., trends in training efficiency affecting school size estimates). No methods are described to resolve these biases.

Suggested solutions to the problem of non-random search or non-random distribution of schools again depended on stratification schemes. This year, it was assumed that geographic strata (stock ranges) "are likely to remain constant, or nearly so," but searching effort within these stock strata was assumed to vary between years. Two data-dependent stratification schemes were discussed: (1) sub-stratifying the stock strata by fishing effort in 1° squares, in hopes of creating sub-strata in which searching effort is random, and (2) sub-stratifying by encounter rate, presumably by 1° squares, in hopes of creating substrata within which dolphin schools are randomly distributed.

The fishing-effort scheme was abandoned because most of the squares experienced little or no fishing effort. The authors suspected that over half the dolphins may occur in these under-sampled squares. As the authors state, this is a major problem because "although searching is close to random in the other substrata, it is far from random in this one."

Stratification by encounter rate was judged more promising, based on assumptions that (1) schools will be randomly distributed in substrata with roughly equal school densities in each 1° square and (2) encounter rates (number of schools detected per nautical mile of searching) smoothed to account for squares with little or no effort, are reliable indices of school density.

No quantitative evaluation of the encounter rate stratification appears in the report (IATTC Annual Report 1985), but the method was judged promising because (1) the substrata generated boundaries similar to contours of geographic elevation on a map and (2) the stratified estimates of abundance were less than unstratified estimates. This latter point is likely an artifact of methodology because stratified estimates are always less than unstratified estimates, if the overall distribution of objects is clumped and search effort is concentrated in the clumps (Edwards and Kleiber 1989).

Problems with the detection probability curve chosen for the line transect analysis were also discussed. Separate sighting functions were estimated for technicians and for crew. The two estimates were then summed to estimate school density. This is because technicians, equipped only with small (7x) binoculars, sometimes see schools on the trackline that are not recorded by the crew. It is assumed that between the two types of observers, all schools on the trackline are recorded. But the detection function for technician sightings does not have, as required for line transect analysis, the required "shoulder" near the trackline. This leads to high variances for the technician-based estimates in addition to suspected but unquantified biases from other sources. If crew members have recorded few schools near the trackline, so that the variance of their estimate is also high, then combining the technician's and crew's estimates produces especially imprecise estimates of school density.

Smearing and more precise initial measurements are recommended to alleviate observed problems with measurement errors in sighting distances and angles. Problems with procedures of data collection to date led to the statement that "this level of rounding error must be reduced before meaningful line transect analyses can be carried out." Smearing "work(ed) reasonably well," although no quantitative results are presented to evaluate the efficacy of the technique.

The fact that school sightings are probably not independent of each other is discussed. Stratifying by encounter rate is suggested to "reduce the problem, but not eliminate it." Seasonal effects are mentioned but not resolved.

Two types of problems with estimating average school size are discussed. Estimated average school sizes can be biased because 1) observers make consistently high or low estimates, or 2) schools sighted are not representative of all schools. Crew estimates in TVOD are 20-30% higher than technician estimates for the same school. Obviously, one or the other (or perhaps both) of the types of observers have been making biased estimates. The solution chosen was to assume the technician estimates are correct and adjust the crew estimates downward.

The second problem may arise if, for example, large schools are seen disproportionately more often than small schools. Because a consistent pattern was not found in existing data, researchers felt that "it is not clear whether adjustments for this type of bias can be made."

1986: Line Transect Analysis Continues

In 1986 (IATTC second quarter report, 1986) the Commission reported that "A procedure has now been implemented for monitoring dolphin abundance. Although there are still a few loose ends, we are able to estimate trends for the various stocks of dolphins in the eastern tropical Pacific (ETP)." This statement refers to the extensive analysis developed by Buckland and Anganuzzi, described in the following section.

1987: Buckland and Anganuzzi: Line Transect Analysis

In 1987, Buckland and Anganuzzi (1988) produced new estimates on dolphin abundance. Reflecting the increase in experience and knowledge gained during the previous year's work with TVOD, their discussion of violations of assumptions contains much more detailed recognition of potential biasing factors, and their analysis includes several modifications to the standard line transect methods, designed to provide more robust estimation.

One major modification was stratification by smoothed encounter rate per 1-degree square, under the assumption that dolphin schools are randomly distributed with respect to searching by tuna vessels, in areas with reasonably similar numbers of schools (stratification by search effort was rejected because so much of the dolphin's range receives little or no effort each year). Smoothed rather than raw encounter rates were used because many 1-degree squares received little or no search effort, but could not be assumed devoid of dolphin schools.

Other modifications include use of Butterworth's (1982) "smearing" method to correct for errors in sighting distances and angles, deleting observer sightings of target species, combining helicopter sightings with binocular sightings, truncation of sightings at 5 n mi, deleting school sightings at angles greater than 100°, deleting sightings made at sea states greater than Beaufort 3 or when observers were off effort, adjusting estimates from 1975/76 for turning by the ship before sightings were recorded, deleting all sightings made on cruises with an average sighting angle less than 20°, and deleting sightings with incomplete data.

Additional improvements included use of the hazard rate model for the line transect detection function, bootstrap rather than analytic variances for the estimates, and proration by stock for spinner dolphin sightings.

Buckland and Anganuzzi discussed the effects of year-to-year changes in effort directed to fishing on dolphin and tested for the possibility that vessels follow seasonal migrations of dolphins. They also pointed out that apparent differences in abundance of dolphin between the low-effort years 1982-1984 and the two subsequent years of high effort could simply be due to the differences in effort. They found no evidence that seasonal movement of vessels correlated with seasonal movement of dolphins.

1988: Further Refinements to Buckland and Anganuzzi's Line Transect Analysis

This work extends the previous year's by including smoothed, stratified estimates of average <u>school size</u> and effective <u>track half-width</u>. The estimates of effective track width are based further on the results of a principal components analysis of correlations between helicopters and birds as sighting cues, and fishing mode as indicated by fraction of all sets that are dolphin sets, in areas where dolphins sets occur. All three estimates (encounter rates, average school size, and effective track width) are expectations derived for a random point within the stock area.

General Comments:

Despite the increasing sophistication of the IATTC's analyses, two major issues remain unresolved. First, major assumptions are still held to be true, despite neither supporting or refuting evidence. A critical example is the assumption that significant biases have been consistent from year to year. If this is true, then trend estimates will be accurate despite the biases because differences between estimates will be due only to differences in abundance. But if the biases change from year to year, differences in estimates will include not only changes in numbers of animals, but changes due to these changes in bias (e.g. Edwards and Kleiber 1989). As yet, the assumption remains unverified.

Second, although many problems with TVOD have been recognized and increasingly detailed attempts have been made to alleviate these problems, the efficacy of these attempts remains unquantified. For example, the stratification schemes undoubtedly help to randomize the data. But whether this randomization has been adequate remains to be demonstrated quantitatively.

While it is true that the methods developed to date do provide estimates that are relatively randomized and unbiased compared to analyses of un-manipulated data, the relationship between these estimates and actual trends in abundance has yet to be demonstrated.

PROBLEMS WITH TVOD FOR ESTIMATING DOLPHIN ABUNDANCE

The previous two sections have described the research programs conducted by NMFS and IATTC for estimating dolphin abundance. Both of these agencies found serious problems with using TVOD to estimate absolute or relative abundance of dolphins. Most of these problems were discovered in the process of trying to apply line transect analysis to the data, but other analyses have had problems as well. This section summarizes these problems, grouped by the type of analysis involved. Much of the information presented here also appeared in earlier sections. It is repeated here because this section is designed to summarize in a single location the problems perceived to date. The section's purposes are to serve as a convenient reference and as an incentive to develope solutions.

Uses to date of TVOD for estimating status of dolphin populations fall into three general categories. In chronological order of appearance, they are 1) catch-per-unit effort (CPUE; SWFC 1972, Stauffer and Oliver 1974), 2) line transect analysis (Clark 1974, Smith 1975, SWFC 1976, Smith 1979, Holt and Powers 1982, Hammond and Laake 1983, Holt 1985a, 1985b), and 3) encounter rate analysis (Polachek 1983, 1987). Problems encountered in each analysis are discussed below in order of their appearance.

1) Catch-per-unit effort

Catch-per-unit-effort has been used only three times to estimate dolphin abundance, and only in very simple form, very early in the era of tuna-dolphin research (SWFC 1972, Joseph and Klawe 1973, Stauffer and Oliver 1974; see also Section I).

In 1973, IATTC researchers "apparently computed expected number of porpoise sets/days fishing" but the manuscript is unpublished (Joseph and Klawe 1973, quoted in Smith 1975). NMFS used a similar measure twice (SWFC 1972, Stauffer and Oliver 1974) before abandoning the approach.

In 1972, SWFC researchers (SWFC 1972) looked for <u>trends</u> in the total number of dolphins (all species combined) involved in the tuna purse-seine fishery by plotting [number of sets on porpoise schools (i.e., catch)]/[Adjusted Standard Days Fishing (ASDF; i.e., effort)] against years 1963 to 1970. Derived from data supplied by the IATTC, the number of sets made on porpoise schools was defined by species group per 1° square per month, made by the tuna fleet within the CYRA and during the unregulated season (Stauffer and Oliver 1974). The effort measure (ASDF) was standardized by relative fishing power of fishing vessels within each season. Fraction of encountered schools set on and average school size were assumed constant. No trend was discernable that could be attributed only to trends in dolphin abundance. Too many other unquantified factors could have caused the apparent pattern.

Stauffer and Oliver (1974) found no trend, but also noted several potential or demonstrated factors other than change in dolphin abundance that could affect the observed trend in the measure "sets/day". These factors included:

a) change in duration of fishing season in the CYRA from all year to the first 4 to 5 months (demonstrated). The quota system imposed in 1966 led to closure of the CYRA by June in subsequent years. This could cause a downward trend in success rate (porpoise sets/ASDF) during later years, when the entire fishery (all boats) concentrated all its effort in this area during the same 4 or 5 months of each year, prior to closure;

b) expansion of the fishery into previously unexploited areas westward of the CYRA (demonstrated). With more area to fish, but the same number of boats, sets/ASDF could decrease even if dolphin abundance did not;

c) changes in vessel efficiency;

1) switching by most experienced captains from class III vessels to super-seiners (demonstrated), reducing efficiency

of class II vessels (potential); possibly offset by tendency for 2)

2) loss of older, less efficient class III vessels from the fleet (demonstrated)

3) increase in the efficiency of fishermen in catching dolphins (potential)

4) increase in the efficiency of dolphin in avoiding fishermen (potential)

d) changes in school size:

Persistent fragmentation of large schools after chases by tuna vessels could produce more dolphin schools and thus increase the number of sets on dolphin (potential);

e) changes in amount of tuna associated with dolphin:

Schools may be ignored (not set upon) if relatively few tuna appear to accompany the school so that dolphin sets/ASDF may reflect abundance of tuna associated with porpoise, rather than abundance of dolphin (potential).

Stauffer and Oliver (1974) concluded that the observed decrease in sets/ASDF could not be ascribed definitively to either changes in activities of the tuna fleet or to changes in abundance of dolphins.

A potentially significant factor not mentioned by Stauffer and Oliver (1974) is that ASDF did not distinguish between the different modes of tuna fishing. Purse-seiners fishing for large yellowfin tuna associated with dolphin do not necessarily follow the same procedures or fish in the same areas as purse-seiners fishing for smaller schoolfish (yellowfin and skipjack) or fish associated with floating logs or debris (e.g., Hammond and Laake 1983). During any year an unidentified and variable fraction of the fleet's effort was directed toward fishing for other types of tuna, rather than dolphin. A downward trend in porpoise sets/ASDF might simply reflect this change in search effort, rather than true changes in dolphin abundance. It was not possible for Stauffer and Oliver (1974) to determine this in their study, because prior to 1972, when NMFS observers on US vessels began recording dolphin vs. non-dolphin effort, only the IATTC's un-categorized data were available for analysis.

Stauffer and Oliver (1974) also extended the 1972 analysis (SWFC 1972) to include data collected during 1971, 1972, and 1973. They found that indices from 1971-1973 were about 40% lower than the indices from 1963-1970 (Smith 1975), but were not confident that the decrease reflected any real decrease in abundance of dolphins.

These discouraging early results with CPUE analysis of TVOD led NMFS to focus on line transect analysis.

2) Line transect analysis

Line transect analysis (LTA) has been the primary method used by NMFS, and the only method used by IATTC, to estimate dolphin abundance. Data for this type of analysis became available from commercial purse-seiners only after NMFS began its observer program in 1972. In addition to data collected for life history studies and mortality estimation, observers were instructed to collect sightings data for LTA. It was not clear at that time whether TVOD satisfied the required assumptions because line transect methods were in a very early stage of development. Despite NMFS' reservations about using TVOD for this purpose, apparently the data were collected anyway "just in case". It is still not clear how effectively TVOD can satisfy the assumptions. Numerous potential and demonstrated problems with TVOD have been listed repeatedly by researchers from both agencies since 1974 (NMFS) and 1979 (IATTC).

LTA of dolphin abundance depends on 4 estimates for each stock or species; 1) school density, 2) average school size, 3) average species composition (species proportions) of schools, and 4) area inhabited. School density is the only estimate strictly related to line transect theory because schools, rather than individual dolphins, are the sighting unit. The major assumptions for LTA thus apply strictly to school density. The other three estimates are required because the obvious sighting object is a dolphin school but the desired result is abundance of individuals in each species or stock.

Although LTA does not use directly estimates of either school size, species composition, or inhabited range, these parameters are discussed in this section rather than separately because they are required to expand the LTA estimate of school density to estimates of stock size.

Problems with deriving estimates of trends in dolphin abundance from line transect analysis of TVOD are categorized below by the parameter most likely affected.

<u>School density</u>. Line transect estimates of dolphin school density are derived from sighting distances and sighting angles recorded for each school observed as the tuna vessel moves along a linear search path. Thus any factor that affects the ability of a researcher on a vessel to see a school of dolphins or that affects timing of data collection can affect the estimates derived from the sighting process.

The basic assumptions that must be satisfied for line transect analysis and the ways TVOD may violate these assumptions were listed in the first study to use TVOD for this purpose (Clark 1974) and have appeared in more or less detail in every study since (e.g., Smith 1975, Smith 1979, Hammond 1981a, Laake

1981, Hammond and Laake 1983, Buckland 1987). Briefly, sighted objects must 1) be randomly distributed with respect to the trackline, 2) not respond to the observer before sighting, 3) always be sighted (never be missed) if directly on the sighting trackline, and 4) the probability of sighting a school must be due only to distance from the trackline (i.e., not affected by school size or sighting conditions).

Tests of whether the assumptions have in fact been violated are moderately common. Methods to overcome these violations and tests of the methods' efficiency are still quite rare.

At least 18 factors have been demonstrated or discussed to date that can affect estimates of school density derived from sightings data. These are listed below, together with suggested solutions where available. Results from analyses of RSOD are included in addition to TVOD, where the same problems appear to plague both data sets.

1) <u>Non-random spatial distributions of sightings:</u>

Clark (1974) tested for randomness by breaking tracklines into segment 60 nautical miles in length and determining the frequency distribution of sightings in different segments. He found the distribution to be significantly contagious (non-random). He ascribed this to 1) the tendency of tuna vessels to seek areas with high density of dolphins, and 2) high potential for resighting the same schools, as vessel re-work "good" areas.

Smith (1975), in a study comparing Clarks' (1974) TVOD with aerial survey data collected at about the same time, also found that sighting distributions within unstratified, 60 nautical mile segments of tuna-vessel trackline were significantly non-random. Too few segments had no sightings and too many segments had greater than one sighting. Smith noted that this could be caused by 1) differences in dolphin school density in different areas (e.g., higher where food is abundant, lower where it is scarce), 2) concentration of search effort in areas where dolphin schools are more abundant, and 3) observers going "off effort" while working up samples after a set, but neglecting to record the time "off effort", so that some times of zero sightings were actually times of zero effort.

Smith (1975) suggested two data analyses to "partially correct for the effects of non-randomness"; 1) stratifying by geographic subarea, and 2) estimating sample variance by subsampling means (Smith 1975). Geographic stratification has been used in greater or lesser detail in every subsequent analysis involving line transect analysis of TVOD (e.g., Hammond and Laake 1983). Subsampling means has not been mentioned or used since. It was not and has not subsequently been specified exactly how these corrections can be evaluated quantitatively.

2) Errors in recording sighting distances and angles (rounding errors):

Clark (1974) presents the first description of problems with rounding errors in recorded sighting distances and angles. Observers collecting TVOD during 1974 tended to round angles to 0, 45, and 90 degrees and to round distances to 0 nautical miles, causing "bumpy" distributions of perpendicular sighting distances. Using the accepted mathematical function for that time (negative exponential) it was impossible to fit an adequate sighting function to this uneven distribution. Hammond and Laake (1983) also found significantly "bumpy" sighting distributions in TVOD and resorted to 'smoothing" (Butterworth 1982). No tests are available to quantify the efficacy of this smoothing technique.

Rounding errors plague research data as well. Holt (1985a) reported that 25 % of all schools sighted during a research survey were recorded as being on the trackline. This is much higher than expected, and implies that observers rounded to zero, sighting angles near the trackline.

3) Non-independent sightings (within and between cruises):

Smith (1975) reported that it was not possible to test whether sightings were independent within a given cruise or between cruises, but that sightings might not be independent within a cruise in "good fishing" areas where vessel captains usually follow a zig-zag course, thus perhaps resighting schools. Sightings may not be independent between cruises when vessels operate in co-operative code groups, as they are known to do.

4) Poor fit of sighting function:

Choice of a mathematical function that adequately fits observed frequency distributions of perpendicular sighting distances has been a problem. Clark (1974) found that probability of sighting a school was not a simple function of distance from the trackline. The mathematical form used for the sighting function in this early phase of LTA fit very poorly the distribution of perpendicular distances from TVOD. There were too many small distances and too few large. More recent analyses have used Fourier series (Holt 1985a) and hazard rate functions (Buckland and Anganuzzi 1988). These fit better, although neither is perfect.

5) Factors affecting perpendicular sighting distances:

Smith (1975) reported that perpendicular sighting distance (as an index of sighting probability) was not affected by species (i.e., spotted, spinner, or mixed), school size (in intervals of 250 animals), or season (early or late). However, perpendicular sighting distance did differ significantly between vessels (from 0.4 to 4.12 nm), was greater in the northern latitudes than southern, and was greater further offshore than nearshore.

Also, the lack of effect with school size may have been due to relative inexperience during these early days of the observer program. Holt (1985a) found that school size affected perpendicular sighting distances during research cruises, with larger schools seen more easily at distance.

6) TVOD density estimates differ from RSOD density estimates:

Another vexing problem has been large discrepancies between TVOD and RSOD in estimates of encounter rate, as well as in estimates of school size and species proportions. Smith (1975) found that estimates of total school density (all data, all species combined) were higher for TVOD than for aerial survey data.

The difference is apparently not due to differences between scientific observers with research vessel versus tuna vessel experience. Cologne and Holt (1984) compared sighting performance of observers with experience only on tuna vessels, against performance of observers with experience only on research vessels. Using data from two research surveys where both sets of observers worked together, Holt and Cologne (1984) found no significant or consistent differences in performance. Research vessel observers detected more schools than tuna vessel observers during one cruise but not during the other. Estimates of school size and species proportions were not significantly different between the two groups of observers.

7) Species differences:

School density estimates are also affected by differences in observed species composition of schools in TVOD versus and RSOD. Estimated school density for spotted dolphins and spinner dolphins was 50%-60% higher (1.45 vs. 0.95 and 0.27 vs. 0.12 respectively) and density of mixed schools about 25% lower (1.03 vs 1.37) in TVOD than in data collected during an aerial survey (Smith 1975).

8) Seasonal differences:

Smith (1975) reported that school density (all species) was much higher in January and February (early season) than during March-June (late season; 3.49 vs. 1.73). This seasonal effect was confounded with concomitant changes in preferred fishing mode and fishing area. School fishing tended to occur early in the year when vessels were closer to shore and within the CYRA. Dolphin fishing tended to dominate later in the year, when the CYRA was closed and vessels were constrained to fishing further offshore.

9) Geographic area:

Smith (1975) found that school densities (all schools, and stratified by school type) in 9 geographic subareas were higher in central areas than north or south. No trend occurred with distance from shore. This was true for both seasons combined as well as for data stratified by season and by area.

In a later study Smith (1979) found that search effort (number of days searched per area), as an index of school density, differed in different areas during 1979 being greatest in equatorial regions. Further stratification into high and low density areas within strata was suggested but not implemented.

10) Sighting cue vs school sighting:

During 1975 and 1976, observers recorded radial distances to dolphin schools when the schools were actually sighted, rather than radial distance to the original cue (SFWC 1976; Appendix 4). The original cue to dolphin school is often bird flocks, seen sooner than the dolphins themselves. It is very likely that the dolphin school will have moved relative to the vessel's trackline by the time the school underneath the flock is finally sighted, thus changing the estimated perpendicular distance to the school and the resulting sighting function. That this occurred was implied by the observed decrease in effective path width (an important component calculation in line transect analysis), from 1.39 nautical miles in 1974 to 0.93 nautical miles in 1975, compared to widths of about 2 nautical miles for both years from research survey data. This problem was recognized and instructions to observers changed in subsequent years, but the effect remains in TVOD from 1975-1976.

11) Vessel turning before cue is recorded:

Tuna vessels may turn toward a school before the crew reports the sighting to the observer. This is implied by the large number of schools sighted directly on the trackline (Hammond and Laake 1983).

12) Vessel avoidance:

Vessel avoidance by dolphin schools, although suspected to affect sighting rates, was found in studies by Au and Perryman (1982) and Hewitt (1985) not to be a significant problem in research surveys. However, authors cautioned that schools might react earlier to other platforms under other survey protocols (e.g., purse-seine vessels with noisier helicopters).

13) Missing schools on trackline:

Small schools directly on the trackline may be missed. Smith (1979) recommended using only data from schools with at least 15 animals.

14) Sea state (Beaufort number):

(See 15)

15) Sunglare:

Holt (1987) reported significant reduction in sighting rates due to sun glare and sea state along the trackline during an aerial survey. Similar problems can be expected from TVOD.

16) Differences in cue sighting probabilities:

Because many dolphin schools associate with birds, and birds are easier to see than dolphins at distance, distant schools that are associated with bird flocks may be seen disproportionately more easily than similar schools without birds. Smith (1979) recommended eliminating sightings further than 1.1 n.mi. perpendicular distance.

17) Platform characteristics:

Differences between vessels in school density estimates may have been confounded with area fished and may have been caused by individual differences in fishermen's ability to sight schools (Smith 1975). For example, some vessels may have fished only in areas where schools of fish were widely scattered, while others fished where schools were clustered closely. Stratifying TVOD by the smallest subdivision possible was suggested as a solution, but not evaluated.

Other characteristics which can be expected to affect sighting rates include physical characteristics of the sighting platform (e.g., deck height, presence of helicopter, number of binoculars and their placement) and searching protocol (e.g., hours searched per day, width of search path, use of helicopter).

18) School size vs probability of sighting:

Clark (1974) found no relationship between school size and radial sighting distance on 5 randomly selected cruises, implying that the assumption of equal sightability (with respect to school size and distance from the sighting platform) was not violated seriously. This is in contrast to Holt's (1985a) later result showing strongly that detectability decreases with decreasing school size and with perpendicular distance from the trackline. The discrepancy is probably due to differences in methods of data collection, and the relative inexperience of observers in the early days of the tuna-dolphin research program, when the data reported in Clark (1974) were collected.

School size. At least 11 single factors have been found to affect estimates of school size derived from either TVOD or RSOD. Although receiving little direct attention, interactions between these factors no doubt also occur. Single factor effects, and interaction effects where noted, are discussed below. Some reports are conflicting, with earlier analyses finding no effects where later analyses, or analyses of RSOD as opposed to TVOD, did find effects. Lack of significance in some analyses (e.g., Brazier 1978, Parks 1985) may be due to lack of power in the analysis used (single-factor ANOVA) rather than to true lack of effect. Neither Brazier (1978) nor Parks (1985) addressed interactions between factors tested in their analyses. Results are reported below for both TVOD and RSOD because factors significantly affecting RSOD are also likely to affect TVOD.

1) <u>Crew vs observer estimates on tuna vessels:</u>

Smith (1975) found that observer estimates from TVOD were only 80% as high as crew estimates of school sizes made from the same sets.

2) <u>Tuna vessels vs research vessels:</u>

Smith (1979), Holt and Powers (1982) and Holt (1985a) found that school size estimates from TVOD were always higher than estimates from RSOD (by a factor of 2 to 5) suggesting that tuna vessels search for and report preferentially sightings of large schools.

Although school size estimates from TVOD still exceed those from RSOD, both sets of estimates have been decreasing yearly. School size estimates from TVOD dropped from about 1000 dolphins/school in 1977 to about 400 in 1983. Estimates from RSOD dropped from about 200 to about 100 during the same period. Hammond and Laake (1983) and Holt (1985a) suggest that these decreases may be due to changes in observer experience and training but this cannot be determined from existing data.

3) <u>Species type:</u>

Smith (1975) found that estimates of spinner dolphin school size were about 1.5 time higher than estimates for spotted dolphin schools.

4) <u>Geographic area:</u>

Smith (1975) found that estimates of school sizes were smaller in northern areas than in the south. Although Brazier (1978) found with ANOVA no significant effect of area on school size estimates, Parks (1985) reported in a later ANOVA that school size estimates were significantly affected by area.

5) <u>Season:</u>

Smith (1975) did not find any difference in school size estimates between early and late seasons, although Brazier (1978) subsequently reported a significant effect of time of year on school size estimates.

6) <u>Year:</u>

Smith (1975) found significant differences between school size estimates in 1973, 1974, and 1975. Brazier (1978) also reported a significant year effect.

7) Distance from sighting platform:

Although Brazier (1978) found no significant relationship between estimates school size and sighting distance, Holt (1985a) reported that large schools are seen more easily than small schools at distances of a few nautical miles from research vessels.

8) Discussion of estimates:

Smith (1979) reported that school size estimates from RSOD were biased by discussion of estimates among observers. When estimates are discussed, observers tend to reach a (biased) consensus, thus biasing the estimate. A similar consensus bias is suspected to occur on tuna vessels.

9) Set type:

Both Brazier (1978) and Parks (1985) used single factor ANOVA to show that estimates of school type were significantly affected by set type.

10) Sighting cue:

Both Brazier (1978) and Parks (1985) used single factor ANOVA to show that estimates of school type were significantly affected by sighting cue.

11) Sun state (glare):

Brazier (1978) found a significant effect of sun glare on school size estimates.

Inhabited range. Smith (1975) showed that estimates of school density and school size differed with choice of geographic range. He suggested that density might decrease toward the periphery but did not demonstrate it.

Appendix 4 of the 1976 stock assessment notes that imperfect estimates of range, inadequate knowledge of within-range variations in density, and suspected relationships between dolphin density and environmental cues (e.g., thermocline) can all lead to poor estimates of dolphin abundance (SWFC 1976). No solutions or tests are described.

"Recent studies by Au et al. (1979), Au and Perryman (1985), Polachek (1983), and Reilly (1984) indicate that seasonal and annual movements may be quite large, and that the area occupied at any one time may be smaller than the known range" (Holt 1985b).

Species proportions. Abundance of each species or stock is derived from LTA as the product of school density, average school size, range, and average species composition of a school.

Species composition is derived by averaging the species proportions of observed schools. Not all observed schools are seen well enough to identify the species. These poorly-seen schools are assumed to have the same average composition as identifiable schools. While these sighted but unidentified schools are not a problem in density estimation, they may affect estimates of both school size and species proportions, if the unidentified schools differ in either average size or species proportions from the identified schools.

Several studies have addressed this problem, and found significant differences between species proportions in TVOD and RSOD (e.g., Barlow and Holt 1984). These differences apparently occur because tuna purse-seiners search preferentially for the large schools of spotted dolphin that are most likely to carry tuna, and appear to "ignore" preferentially those schools with little promise of carrying tuna.

Barlow and Holt (1984, 1986), in an extensive study of species proportions estimated from TVOD, aerial surveys, and research vessel surveys found:

1) considerable geographic variability in species proportions of observed schools,

2) significant differences between TVOD and research surveys,

3) significant effects ($p < 0.05$) of perpendicular distance, sighting cue, school size, year, and season. Sea state, effort, distance from previous sighting and use of helicopter were not significant.

They concluded that TVOD were unacceptable for estimating species proportions because tuna vessels search preferentially for some species, so that recorded proportions are biased.

3) Encounter rates

Polachek (1983), aware of the questions raised about line transect analysis of TVOD, investigated the use of simple encounter rates (schools observed/linear distance searched) as an index of dolphin abundance. He devised a statistical method to test search tracks of individual vessels for non-random patterns, and found that tuna vessels tend to operate in two modes: "running" between areas, and circling within smaller areas. Search was significantly non-random at the smallest scale he could test (2° squares); search patterns were less random at larger scales (5 degree squares).

Encounter rates of spotted dolphin were affected by geographic area, sea state, and observer effort. Polachek discussed several major unresolved problems with using TVOD to estimate dolphin abundance, including:

1) non-uniform search effort in space and time, violating the assumption of non-random search by vessels relative to distribution of dolphin schools,

2) vessels not searching independently (e.g., searching instead as part of a co-operating multi-vessel code group), so that individual vessels cannot be considered replicate sampling units,

3) observers needing to rely on crew for information about sighting schools, introducing unquantifiable biases in the data,

4) preferential search for some species and school sizes, and

5) unreliable estimates of school size.

Polachek concluded that encounter rates did not appear to provide useful estimates or indices of abundance.

4) Other problems with TVOD for estimating dolphin abundance

Disproportionate and inadequate sampling of international fleet. The number of US boats has been decreasing and the number of non-US boats increasing. IATTC's annual reports show that in 1984, U. S. vessels comprised 44% (72/165) of the total number of purse-seiners fishing in the ETP. In 1985, only 39% (67/172) were U.S vessels; in 1986, only 36% (58/159). This is important because until 1986, the majority of trips by observers were made on U.S. vessels, despite the fact that U. S. vessels no longer make the majority of trips. NMFS observers sailed only on U.S. ships; IATTC observers sailed mostly on U.S. ships (IATTC Annual Reports). This disproportionate sampling occurred primarily because Mexico, whose purse-seine fleet is almost as large as the U.S fleet and whose capacity exceeds the U.S. fleet, did not participate in the observer program until 1986 (IATTC Annual Reports). Thus, prior to 1986, relatively little of the non-US fleet was being sampled. It cannot be established with existing data whether or not extant TVOD are representative of the entire international fleet.

Area fished. Areas fished and distribution of effort within those areas changes from year to year and from season to season within the general fishing areas of the eastern tropical Pacific (Hammond and Laake 1983, Buckland and Anganuzzi 1988). In addition to these relatively small scale changes, less frequent large scale exploratory movements have been occurring to (and from) the western Pacific (Patterson and Alverson 1986) and south of the equator (see also section III). There is little reason to believe that the differences in oceanographic characteristics between these areas are not also reflected as differences in dolphin distribution and abundance between these areas. By implication, biases in data collection or analysis may not be consistent either between these areas, or over time within these areas. Trend estimates based on the assumption that biases have been consistent could be seriously in error (Edwards and Kleiber 1989).

Dolphin behavior. It has been suggested but not proven that dolphins have become increasingly difficult to catch and that dolphin schools have become progressively fragmented after years of chasing by tuna boats. This could be reflected in TVOD as fewer dolphins sets and smaller estimated school sizes. Both of these effects might lead to a conclusion that stocks sizes had decreased, when in fact dolphin schools had simply changed in behavior and average size.

Summary

The analysis of TVOD in monitoring dolphin abundance is comfounded by:

1) Searching and fishing effort by the tuna fleet are not random. Areas and concentrations of effort, and type of effort (fishing mode) vary in both time and space. Vessels apparently concentrate more effort on dolphin species that carry tuna than on species which don't.

2) TVOD are not as abundant as they appear. The biases in TVOD caused by the heterogeneity in search and fishing effort can be removed or factored out by adequate stratification of the data. But even with the tremendous number of observed days at sea, it has not been demonstrated incontrovertibly that stratifications used to date have truly been effective in accounting for all significant biases. The problem is that inheterogeneity may still exist even within the smallest possible strata.

For example, it is possible that non-random clustering of dolphin schools and searching by tuna vessels occurs on scales smaller than 1° squares. If so, aggregating TVOD by 1° squares violates the fundamental assumption of homogeneity within strata. In this case, it would be more proper to aggregate on a smaller spatial scale, e.g., 0.5° or 0.25° squares. But stratifying on a scale this small results in assigning so few TVOD to each stratum that statistical analyses have almost no power. The practical limit for geographic stratification of TVOD is apparently 1° squares (Buckland and Anganuzzi 1988).

3) Environmental characteristics apparently affecting dolphin distribution and abundance are neither homogenous nor constant from year to year, or even season to season. For example, the marked changes in oceanographic conditions during the El Niño of 1983 were accompanied by a precipitous, biologically impossible, and isolated dip in estimates of dolphin abundance for that year (Buckland and Anganuzzi 1988).

4) Coverage of the fleet by observers is not representative. Most observers sail on US vessels, but most of the fleet is now non-US. The largest fleet of non-US vessels (Mexico's) only recently began to permit observers on it's ships.

5) Individual vessels cannot be considered replicates. Competence and experience of captains and crew vary from vessel to vessel. Boats often fish interactively in un-identifiable code groups with variable membership. The amount and type of information transferred to the observer by the crew varies tremendously, depending on the observer's interactions with the skipper and crew.

6) Composition within fishery is not constant. Fishing methods are not necessarily the same for each country's vessels. Similarities and differences have not been investigated or quantified.

7) Geographic range, school size, species composition of schools and behavior of ETP dolphins are not constant from year to year.

8) Data collection procedures introduce artifacts. Sighting angles, sighting distances, school size estimates, and species composition estimates from TVOD have all been demonstrated to contain bias. Helicopter searching may have greatly affected the search tracks of vessels relative the distribution of dolphin schools. Observers do not collect most sightings data themselves, but must rely on the vessel and helicopter crew to relay the information to them, with unquantifiable accuracy.

9) Fishermen are looking for tuna, not dolphin per se. This affects the relationship between effort on dolphins, and true abundance of dolphin. Many factors totally unrelated to the true abundance of dolphins are affecting the estimates of abundance derived from TVOD.

Despite these problems, TVOD represent an unprecedented source of information about the distribution and abundance of pelagic cetaceans in the eastern tropical Pacific Ocean. The extensive (and in some large areas, intensive) effort by the tuna purse-seine fleet has provided us with accurate times and positions for hundreds of thousands of cetacean sightings over a period of almost 2 decades. Such a quantity of records simply does not exist for any other area or complement of marine mammals.

The types of biases and artifacts affecting TVOD collection and analysis are generic to commercial fisheries data, and while serious, should not preclude efforts to utilize this unique, abundant, relatively inexpensive, and continually expanding data source. Focus on reducing or eliminating artifacts of data collection and on improving stratification strategies by investigating correlations between environmental characteristics and dolphin distributions could help to alleviate most of the problems outlined above.

The future of TVOD as an effective basis for estimating dolphin abundance in the ETP depends primarily on developing methods to recognize and either eliminate or quantitatively minimize these flaws.

DATA TYPES AND COLLECTION PROCEDURES

Previous sections have summarized the ways in which NMFS and IATTC have used TVOD to estimate dolphin abundance, and the problems these agencies have found or suspected with these data. This section describes the types of TVOD collected by NMFS and IATTC, and discusses the similarities and differences between the data types and collection procedures for each agency.

Two types of data collected from the tuna purse-seine fishery in eastern tropical Pacific Ocean are useful for management of the marine mammal stocks affected by the fleet's fishing activities. These are 1) data recorded in bridge logs by tuna vessel captains and crew, and 2) data recorded by scientific observers accompanying vessels on routine fishing trips. NMFS and the IATTC collect two different versions of these two data types.

Basic characteristics of each type of data as collected by each agency are discussed below.

I. Bridge log data

A) NMFS "Bridge Log" (MARINE MAMMAL LOG SHEET; Figure 2). This was a chronological list of all sets made on dolphins during each cruise by every U.S. tuna purse seiner certified to fish on dolphin. This record was not required to include information about non-dolphin sets. Generally, one day's effort was recorded on one page. Captains of U. S. vessels were required to keep these bridge logs from 1975 through 1984. The log is kept on each vessel's bridge and filled out by the captain. Requested for each dolphin set are date, time, position, number and species of marine mammals involved in the set and tons of tuna caught.

B) IATTC "SEINER FISHING RECORD AND BRIDGE LOG" (Figure 3). This is a voluntary record, requested by the IATTC of all tuna purse seiners fishing in the eastern tropical Pacific Ocean (both U.S. and non-U.S.). The record was designed primarily for gathering information relevant to management of ETP tuna stocks rather than for conservation of marine mammals. Management of tuna stocks in the ETP is IATTC's primary charge; investigations of the "tuna-dolphin problem" are secondary, and did not begin in earnest until 1979. The bridge log provides little space for information specific to dolphin fishing.

The IATTC bridge log record is similar in design to the NMFS bridge log. Each uses one printed line per set and usually one page per day. But there are three major differences between the IATTC and NMFS "bridge logs". The IATTC log 1) has almost no facility for entering information about dolphin fishing or mortality, but requests somewhat greater detail about tuna catches, 2) is (ideally) a record of ALL sets made, not just dolphin sets, and 3) tends to be proprietary information.

Information about marine mammals is limited because it is requested in the IATTC bridge log only under "type of school". This could be, in addition to dolphin fish, either school fish or log fish. Generating a record of ALL sets made is important because it provides a much more complete picture of the vessel's activities (movements in space and time) during each cruise, than available from the NMFS bridge logs which record only dolphin sets. The proprietary nature of the IATTC logs is unfortunate because of the importance these data have for elucidating search dynamics of the purse-seine fleet. The captains of the vessels are understandably unwilling to provide potentially valuable information to their competitors.

II. Observer data

A) DATA COLLECTED BY NMFS OBSERVERS. NMFS observers on tuna purse-seiners collect seven types of primary data. Listings of the data types and procedures for collecting them appear in handbooks prepared by personnel at the NMFS Southwest Region Office. These handbooks are issued to observers before they leave on their first cruise. The data types are collected roughly in chronological sequence during a cruise, and include:

1) CRUISE SPECIFICATIONS RECORD.
2) FISHING MODE RECORD
3) MARINE MAMMAL WATCH DAILY EFFORT RECORD
4) MARINE MAMMAL SIGHTING RECORD
5) SCHOOLFISH AND FLOTSAM SET LOG
6) MARINE MAMMAL SET LOG
7) PORPOISE LIFE HISTORY FORM.

These seven types of data are subsequently redistributed into various data bases by Data Management groups at the Southwest Fisheries Center and the Southwest Fisheries Regional Office of NMFS. These redistributed data bases are discussed in detail by Oliver (1983, Porpoise Data Management Program, unpubl. MS, and MS in prep., 1987), and not considered further here.

A brief description of the seven primary data types follows. More detailed information can be found in Meyer (1987 Tuna/Porpoise Observer Data Manual) and Oliver (Data review, MS, in prep).

1) CRUISE SPECIFICATIONS RECORD (Figure 4): primarily information on vessel and gear characteristics. There will be one record per trip.

2) FISHING MODE RECORD (Figure 5): This is used to derive a measure of effort titled "standard day's fishing" for U. S. (not non-US) tuna purse seiners. The record is relatively general and pertains to 4 types of vessel activity; <u>searching</u>, <u>chasing</u>, <u>setting</u>, or <u>inactive</u>. It does <u>not</u> include information about the type of fishing being done, i.e., it does NOT distinguish between search effort directed toward school fishing, log fishing, and dolphin fishing. This lack of information is important because search patterns and techniques differ between the different types of fishing. For example, search paths for school fish and log fish tend to be narrower than search paths for dolphin fish.

It is also important to distinguish NMFS' use of the phrase "fishing mode" from IATTC's use of the phrase. IATTC researchers use this phrase to distinguish between the types of search effort expended and tuna sought; i.e., log fish, school fish, or dolphin fish.

Changes within the searching mode are recorded if "long-term" changes occur in non-fishing factors that affect searching, e.g., vessel speed, number of binoculars in use, radical change in weather or sea condition (in particular, whitecaps) and whenever a helicopter takes off or lands. "Long-term" is not precisely defined.

This FISHING MODE RECORD pertains to the searching effort of the tuna vessel for fish. It is NOT the same as the <u>observers</u> searching effort for marine mammals (see 3) and 4) below). The crewmen will be looking for tuna, and may or may not use sightings of marine mammals to find those tuna. The <u>observers</u> are interested ONLY in marine mammals, and will be searching for ALL marine mammals. The crewmen will be most interested in seeing those marine mammals likely to be associated with tuna (i.e., schools of spotted and spinner dolphin). Thus crewmen may ignore and so not report other species despite the observer's interest.

3) MARINE MAMMAL WATCH DAILY EFFORT RECORD (Figure 6): This information has been or is used together with the MARINE MAMMAL SIGHTING RECORD, for analyses of encounter rate (Polachek 1983), school size (Holt and Powers 1982, Holt 1984b), species proportions in dolphin schools (Barlow and Holt 1984, 1986), and relative abundance of various stocks and species of dolphins affected by interactions with the purse-seine fishery (Buckland 1987).

The MARINE MAMMAL DAILY WATCH EFFORT RECORD records the <u>observer's</u> effort in watching for marine mammals while the vessel is searching for fish. The observer is supposed to be on the bridge and looking for marine mammals whenever sighting conditions permit, and whenever he is not occupied working up animals collected during a previous set. Ideally this would be sunrise to sunset. In reality, 4-6 hours effort per day is more common (A. Jackson, SWFC, pers. comm).

The observers are requested not to record watch effort data if the ship is in a "schoolfish area" where marine mammals are not expected and where the vessel is expected to turn frequently.

Information recorded here primarily allows NMFS researchers to reconstruct the cruise tracks of the vessel and environmental conditions as the vessel moves about searching for and capturing tuna. This set of data does not include information about mammals observed, or characteristics of the sets made.

Observers themselves are not always looking for mammals. Observers are equipped with 7X or 10X binoculars, which are much less effective for sightings at distance than the crew's high power glasses (20-25X). Much of an observer's effort consists actually of relying on crewmen or the helicopter pilot to report sightings of marine mammals, rather than making the sightings himself. Observers are told in training that they do not need to use their binoculars if the crew is actively searching for signs of fish because the crew's glasses are so much stronger. Few large schools of target-species dolphin (spotted, spinner and common dolphin) make it close enough to the boat for the observer to see them without having been sighted already by the crew (IATTC Annual Report 1986). Observers may be more likely to see non-target schools (Barlow and Holt 1984) ignored by the crew, but this effect has not been quantified.

The watch effort record is recorded as a sequence of "legs", with legs grouped into "series". New legs begin whenever some condition changes that would affect the observer's (or the crew's) ability to look for marine mammals (i.e., whenever "effort" must be redefined). These conditions include changes in course, speed, helicopter takeoff or landing, and Beaufort stage (wind speed).

Although some of the same information is required in both the MARINE MAMMAL WATCH DAILY EFFORT RECORD and the FISHING MODE RECORD, the MARINE MAMMAL WATCH DAILY EFFORT RECORD is (or should be) a more detailed chronology of events. Although both require records of changes in, for example, Beaufort stage or weather, only "long-term" changes are to be recorded in the FISHING MODE RECORD.

In general, the MARINE MAMMAL DAILY WATCH EFFORT RECORD records the time and position of changes in vessel course, speed, helicopter activities, Beaufort stage, fog/rain, and sun position.

4) MARINE MAMMAL SIGHTING RECORD (Figure 7): This data form includes records of ALL marine mammal sightings, regardless of whether the daily effort record is being kept (i.e., regardless of whether the observer was officially on effort). An individual

sighting is defined as any distinct aggregation of marine mammals, regardless of whether the aggregation contains one or more than one species or stock.

These data include the place and time of sighting, the sighting cue, who made the sighting, what kind of equipment was used to make the sighting (binoculars, helicopter), environmental conditions, estimates of direction and distance to the sighting, and estimates of school size and species composition (as percentages). Estimates of school size and species composition are collected from up to 3 crewmen as well as the observer. Observers are explicitly instructed not to guess about species identifications.

This record "should contain the best and most complete estimates of both school size and species composition". Estimates are also made during the set, but those made during sighting are more important for at least two reasons. First, the net usually captures only a subset of the animals sighted originally. Second, the observer has more time during the period of sighting and chase than during the set to make observations of the school.

5) SCHOOLFISH AND FLOTSAM SET LOG (Figure 8): These data are collected whenever the net is set but marine mammals are not involved. Usually this will occur during sets on small yellowfin or skipjack (school fish set) or floating debris (flotsam or log set), during "water hauls" to wash the net, or to test some aspect of the gear. Basically this is an abbreviated version of the MARINE MAMMAL SET LOG.

6) MARINE MAMMAL SET LOG (Figure 9): These data include characteristics of the set and of marine mammal kill such as species, age category, color pattern in spotters, number killed, effectiveness of release methods, and observations pertaining to U.S. Marine Mammal Regulations.

7) PORPOISE LIFE HISTORY FORM (Figure 10): These are morphometric data, some recorded in the field (length, sex, other dimensions), some recorded in the lab from specimens collected and preserved by observers (maturity, reproductive state).

B) DATA COLLECTED BY IATTC OBSERVERS. Observers from IATTC collect basically the same information as observers from NMFS, but in somewhat less detail, and in some cases with rather different definitions for given variables. Differences are discussed in a subsequent section (C).

Listings of the data types, procedures for collecting them, and examples of completed forms appear in handbooks prepared by IATTC personnel (Bratton et al. 1986). As with the NMFS observer program, these handbooks are issued to IATTC observers during their training period prior to their first cruise.

IATTC observers collect 4 primary types of data:

1) VESSEL RECORD (similar to NMFS CRUISE SPECIFICATIONS RECORD)
2) DAILY ACTIVITY RECORD (combines NMFS FISHING MODE RECORD and MARINE MAMMAL WATCH DAILY EFFORT RECORD)
3) MARINE MAMMAL SIGHTING AND SET RECORD (combines NMFS MARINE MAMMAL SIGHTING RECORD and MARINE MAMMAL SET LOG)
4) SCHOOLFISH AND FLOTSAM SET RECORD (almost the same name as NMFS SCHOOLFISH AND FLOTSAM SET LOG, but collects many fewer data)

As with the NMFS primary data forms, after an IATTC observer returns from a cruise with completed primary data forms the data are re-distributed into various data bases by IATTC personnel.

A brief description of the variables requested by the 4 types of forms follows.

1) VESSEL RECORD (Figure 11): This contains information about gear and vessel characteristics, dates of departure and return, and identities of captain and observer. There will be one record per trip.

2) DAILY ACTIVITY RECORD (Figure 12): This form is used to record events sequentially in time, with one line per event and generally one double-sided form per day. Events are changes in any factor that leads to changes in search effort, i.e., the ability of the vessel and crew to sight fish. Events related to fishing activity include: depart, run, search, cue, mammal sighting, chase, drift, tuna set, mammal set, log set, end set, and arrive in port. Events recorded regardless of a change in any of these activities include: technician going on or off effort, recording position every 2 hours, change in number of high-powered binoculars in use, or changes in water temperature or sea state during searching activity.

Unlike NMFS observers, IATTC observers are specifically requested to distinguish, if possible, in the event record between searching for schoolfish and searching for fish associated with dolphin

Data collected at each event include time and position, sighting distance and bearing from the ship, ship speed, weather conditions, whether aerial assistance was involved, and the tonnage of yellowfin, skipjack or other tuna caught (if the event was a successful set).

3) MARINE MAMMAL SIGHTING AND SET RECORD (Figure 13): All sightings of marine mammals and all sets on fish associated with marine mammals are recorded on these forms. Occurrence of either a sighting or set is also recorded in the DAILY ACTIVITY RECORD, but the information is much less detailed than that recorded in the MARINE MAMMAL SIGHTING AND SET RECORD.

THE MARINE MAMMAL SIGHTING AND SET RECORD contains estimates of school size and species composition of all marine mammal aggregations sighted by anyone on the vessels. Estimates are requested from three crew members as well as from the observer. This log also requests relatively detailed information on behavior during chase, set and release, the number and species composition of dolphin captured and of dolphin killed, and performance of net and crew during the set.

4) SCHOOLFISH AND FLOTSAM SET RECORD (Figure 14): This record is kept for all sets made on tuna not associated with marine mammals. No information about catch (or lack of it) is kept on this record (catch information is recorded on the DAILY ACTIVITY RECORD). The majority of the information requested relates to gear performance and description of malfunctions.

III. Differences between NMFS and IATTC data records and collection

Although both agencies collect similar data for similar reasons, the procedures and forms used by NMFS and IATTC observers are not the same. Similarities and differences in collection of the various types of data are discussed below.

1) CRUISE SPECIFICATIONS RECORD (NMFS) vs VESSEL RECORD (IATTC)

These differ very little. Both are concerned primarily with describing vessel capacity and gear.

2) FISHING MODE RECORD and MARINE MAMMAL DAILY WATCH EFFORT RECORD (NMFS) vs DAILY ACTIVITY RECORD (IATTC)

One of the major differences between data collection by NMFS vs. IATTC observers is that IATTC procedures tend to combine the FISHING MODE RECORD and the MM DAILY WATCH EFFORT RECORD into a single form (the DAILY ACTIVITY RECORD), somewhat simplifying the data collection process.

NMFS observers are required to keep two time-sequential logs with a one-line-per-event format: the FISHING MODE RECORD and the MARINE MAMMAL DAILY WATCH EFFORT RECORD. Basically, the FISHING MODE RECORD describes relatively infrequent events relating to major changes in vessel activity (i.e., from search to chase to inactive). The MARINE MAMMAL WATCH EFFORT RECORD is a much more detailed time-sequential record of changes in any factor that might affect sightability of marine mammals. The effort record is divided into series of legs, each leg corresponding to a period when conditions are not changing. The mode record requires a notation only when the fishing mode switches between searching, chasing, or inactivity, or when a "long term change" occurs within a mode.

Observers must switch from one form to the other when events occur that need to be recorded on both forms, and some of the information is redundant (e.g., both forms require vessel speed, water temperature and sea state). Neither of these records contains any information about the results of a chase or set; that information (e.g., tons and types of tuna caught) appears on the set logs.

IATTC observers fill out only one time-sequential log with a one-line-per-event format, using the IATTC's DAILY ACTIVITY RECORD. Tons and types of tuna caught during each set, regardless of the type of set, appear on the line of the record associated with the set. The type of set (schoolfish, log fish, dolphin) is inferred from this form by the EVENT recorded for that set's line on the form. This differs from the NMFS forms, where tons and types of tuna caught appear in the MARINE MAMMAL SET LOG if the set was made on marine mammals, and in the SCHOOLFISH AND FLOTSAM SET LOG if the set was made without involving marine mammals.

Another major difference between data collected by NMFS and IATTC observers is in each agency's definition of "effort". IATTC observers are "on effort" when "purposefully in the vicinity of the bridge to observe the vessel's operations and to collect accurate data on marine mammal sightings". Absences of greater than 5 minutes are to be recorded as "off effort." NMFS observers "are to be on the bridge keeping a lookout for marine mammals and recording their searching effort on the MARINE MAMMAL WATCH DAILY EFFORT RECORD, when the vessel is under way and conditions are favorable for sighting marine mammals." Thus IATTC has a somewhat more stringent definition of when effort <u>is</u> occurring, but NMFS is more definite about when effort <u>should be</u> occurring.

3) MARINE MAMMAL SIGHTING RECORD and MARINE MAMMAL SET LOG (NMFS) vs MARINE MAMMAL SIGHTING AND SET RECORD (IATTC)

<u>Sightings</u>. The NMFS MARINE MAMMAL SIGHTING RECORD combines variables from two IATTC records: the DAILY ACTIVITY RECORD and the MARINE MAMMAL SIGHTING AND SET RECORD. Sighting cues, distances, and bearings to sightings are recorded on the IATTC DAILY ACTIVITY RECORD, while estimates of school size and species composition appear on the MARINE MAMMAL SIGHTING AND SET RECORD. The two records are related via times and set numbers recorded on both records. The IATTC strategy of data recording is to branch off from the DAILY ACTIVITY RECORD to the SIGHTING AND SET RECORD <u>after</u> recording the characteristics of a marine mammal sighting (e.g., distance and bearing). NMFS procedures require observers to begin a MARINE MAMMAL SIGHTING RECORD as soon as a cue is seen.

It is not clear from the NMFS observer training manual what happens to sighting records begun for a cue that did not lead to sighting marine mammals. Apparently, they are discarded. Thus NMFS records contain information only about those cues which actually led to sighting marine mammals.

In the IATTC DAILY ACTIVITY RECORD, all cues leading to a marine mammal sighting or set, a tuna set, or a log set, are recorded. Thus IATTC records contain information about all cues that led to significant events, not just those leading to sightings of marine mammals.

Apparently neither agency keeps a record of cues that did not lead to sighting mammals or fishing. Also, neither agency keeps a record of the distance and bearing, or position of the ship, when marine mammals are sighted after a cue. This can be a problem when the cue (i.e., birds) was originally sighted over the horizon.

IATTC explicitly instructs observers NOT to record distance or angle to marine mammals sighted as a result of a previously recorded cue. A cue and the corresponding marine mammal event are given the same sighting number.

Estimates of school size and species composition. Both NMFS and IATTC observers make estimates of school size and species composition of all sighted aggregations of marine mammals, as soon as possible after the initial sighting. Both sets of observers also ask up to three crew members, and either the fish spotter or the pilot if the sighting was by helicopter, to make estimates. The agencies differ in where this information is recorded, and how the estimates from crew members are treated. The estimates appear on the first of eight potential pages of the IATTC MARINE MAMMAL SIGHTING AND SET RECORD. NMFS observers record the estimates on the MARINE MAMMAL SIGHTING RECORD.

On IATTC forms, the observer notes 1) the individual estimates from three crew members of number sighted, and the median estimate of number sighted, indicating specifically if one of these was the captain, and 2) individual and averaged estimates of species composition.

On NMFS forms, observers record the highest, lowest, and calculated average (rather than median) of the crew's three estimates of school size, and the averaged estimates of species composition. No individual species composition is recorded unless only one stock was present.

Chase and set. If a sighting leads to setting on the school of marine mammals, both NMFS and IATTC require additional estimates of school size and species composition to be made by the observer and crew. Before the net is released, NMFS observers are required to make estimates of school size and species composition, and to ask three crew members for estimates. One of the three must be the captain. ALL THREE of these estimates are recorded on page 1 of the NMFS MARINE MAMMAL SET LOG, which is now begun because a set is imminent. NMFS observers estimate school size and species composition again during encirclement, and after capture. Crew estimates are requested again only after capture, as the crew is obviously busy during encirclement. Again, ALL estimates are recorded, not just averages.

IATTC observers do not make estimates during encirclement, but do make estimates and ask three crew members (including the captain, in particular) to make estimates after capture. These are recorded in the same manner as the initial estimates at sighting. IATTC observers then make a final "best estimate of number and species composition of the entire school".

Thus both NMFS and IATTC observers make estimates three times between initial sighting and release. Two of the estimates are made at similar times (at initial sighting and after capture) by both observer and crew. The third is made only by the observer, and is made at different times. The NMFS observer makes the third estimate during encirclement. The IATTC observer makes the third estimate after the set is completed, based on observations of initial abundance, behavior and escapement during the set, capture estimates, and estimates of number released. NMFS observers record a comparable "best estimate" on the sighting record.

Both sets of observers estimate numbers and species composition of marine mammal mortality during the set.

Most of the other information recorded on both NMFS and IATTC SET RECORD forms are not concerned with data that are used to estimate dolphin abundance, but rather with technical details of net configuration, crew procedures, and recording of possible malfunctions

4) SCHOOLFISH AND FLOTSAM SET RECORD (IATTC) vs SCHOOLFISH AND FLOTSAM SET LOG (NMFS)

Very little information is requested on either of these forms. Other than set number and time, the IATTC form requires no further information unless a malfunction occurs. If so, there are spaces to describe briefly the circumstances of the malfunction. The NMFS form requires information on environmental conditions, timing of set, and estimates of tons and types of tuna caught, in addition information about characteristics of the set and possible malfunctions. The additional information required by the NMFS forms is not left unrecorded by IATTC observers, but appears instead on the IATTC DAILY ACTIVITY RECORD.

Thus both agencies collect both gear and catch information for schoolfish and logfish sets, but record some of that information in different places.

5) PORPOISE LIFE HISTORY FORM (NMFS)

Both NMFS and IATTC observers carry to sea identical instructions about collecting life history information.

IV. Interchange of data between NMFS and IATTC

Both agencies use both sets of data, but because the IATTC program is voluntary and depends to a large extent upon the goodwill of the international fleet, IATTC tends to release only summary forms of the data collected by it's observers. IATTC's objective is to protect the identity of individual vessels.

As is the case with IATTC's data, NMFS data are available to NMFS researchers, but are not entirely accessible to the general public. Although NMFS data are subject to the Freedom of Information Act, the General Council's office has determined that certain of these data contain "trade secrets" and cannot be revealed in such a way as to compromise the competitive ability of a vessel or the fleet. Access to these data are controlled by the Southwest Regional Office of NMFS upon the advice of the Office of the General Counsel.

CONCLUSION

TVOD may or may not be a sufficiently reliable data source for estimating dolphin abundance in either absolute or relative terms. Methods do not yet exist to alleviate completely the problems identified to date. Neither do tests exist to evaluate the efficacy of methods existing or proposed to alleviate these problems. All fishery data have similar problems with representing poorly the true situation of field populations. The major question, unresolved for TVOD, is <u>how</u> poorly. This cannot be determined from TVOD alone.

Ideally, these problems might be solved by stratification. But two fundamental problems occur: 1) appropriate strata appear to be too small to contain more than a few data points each so that estimates from each stratum are quite imprecise, and 2) there is simply no way to test with TVOD alone whether the stratification actually "worked". Some sort of "ground truth" (experimental control) is required.

This could be accomplished in either of two ways: 1) comparison of estimates derived from TVOD with estimates derived from truly representative data collected concurrently (i.e., from research surveys) or 2) through simulation studies. Both approaches are being pursued currently by NMFS (Reilly 1987, Edwards and Kleiber 1989); the jury is still out.
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TABLES

Table 1. Number of vessels and composition of international tuna purse-seiner fleet operating in the eastern tropical Pacific Ocean. Data from IATTC Annual Reports, Table 2.

Year	United States	Mexico	Ecuador[a]	Total[b] Non-U.S.	Total Non-U.S.+U.S.
1979	138	25	41	121	259
1980	126	46	41	123	249
1981	128	45	36	118	246
1982	123	43	29	97	220
1983	100	49	29	99	199
1984	73	47	26	92	165
1985	67	53	30	105	172

[a]most of Ecuador's catch is skipjack, implying relatively little interaction with dolphin schools because few skipjack co-occur in dolphins in the ETP

[b]includes fewer than 15 vessels each from other countries; most have fewer than 5.

Table 2. Number of trips (observed and total) by tuna purse-seiners operating in the eastern tropical Pacific Ocean. Numbers of trips do not exactly match numbers of trips listed in Table 4, because different definitions were used to allocate inter-year trips to one year or the next. Data in this table taken primarily from IATTC Annual Reports.

Mexico is reported separately Because it's fleet is almost as large as the U.S. fleet, but little is known about it's interaction with dolphin schools. This is because the Mexican fleet declined to participate in the IATTC program until 1986. The point of the table is to show the relative importance, in term of numbers of cruises, of U.S. and non-U.S. fleets.

Year	Trips Observed (U.S.)	(NMFS, IATTC)	Trips Total (U.S.)	% Coverage	Trips Observed (Mexico)	Trips Total (Mexico)	Trips[e] Observed (non-U.S.)	Trips[e] Total (non-U.S.)	% Coverage
1979	98	(67,31)	206	48	0	??	5	152	3
1980	98	(43,55)	195	50	0	??	8	163	5
1981	98 a	(34,55)	192	51	0	??	4	149	3
1982	72 b	(29,43)	213	34	0	??	8	105	8
1983	37 c	(0,37)	109	34	0	??c	27	633 d	4
1984	30	(11,19)	??		0	??	4	??	
1985	49	(23,26)	122	40	0	135	17	81	21

[a] from Tables 1 and 2 in Hammond 1984

[b] from Table 1, Wahlen et al. 1986

[c] 50% of non-U.S. sets were made by Mexico in 1984 (Hall and Boyer 1986)

[d] Samples and total trips by non-U.S. purse-seiners in ETP, 1979, 1983 from Table 2, Hammond and Hall 1985.

[e] including Mexico

Table 3. Number of sets (observed and total) by tuna purse-seiners operating in the eastern tropical Pacific Ocean. Data from Hammond and Isai 1983, Hammond 1984, and Hammond and Hall 1985.

Year	Sets Observed (U.S.)	Sets Total (U.S.)	% Coverage	Sets Observed (non-U.S.)	Sets Total (non-U.S.)	% Covered	Sets Observed (U.S.-non U.S.)	Sets Total (U.S.-non U.S.)	% Coverage
1979	2951	6197	48	110	2355	5	3061	8552	36
1980	2154	5259	41	110	2707	4	2264	7966	28
1981	2277	5635	40	79	2646	3	2356	8281	28
1982	1828	4568	40	163	1881	9	1991	6449	31
1983	862	2853	30	487	1038	4	1349	13891	10

Table 4. Number of sets (top of each pair of numbers) and number of cruises (bottom of each pair of numbers) during which TVOD were collected by observers on tuna purse-seiners operating in the eastern tropical Pacific Ocean. Each column shows entries for a particular data type. The 10 columns represent the 10 largest subsets of TVOD. The point of the table is to show the magnitude of the data set, and by implication, the magnitude of the problems associated with analyzing the data. Data from Oliver (1983; Porpoise Data Management System, unpubl. MS, Table 1).

Year	CS[a]	VR[b]	SL[c]	TY[d]	KL[e]	PK[f]	ME[g]	MS[h]	RE[i]	RS[j]	LH[k]
pre 1971	5					15					489
1971	8		199	68		51	133	511			559
			6	6		6	3	6			
1972	14		354	276		273	478	820			1318
			13	13		13	13	13			
1973	26		1006	773		752	1221	2706			3942
			25	25		24	16	25			
1974	44		1970	1130	1130	1130	2391	3577			3061
			42	40		40	32	43			44
1975	36	12901	1802	1102	1102	1102	4499	4418			3924
		33	35	34	34	34	33	33			
1976	81	27117	3060	1303	1298	1303	7902	7847			2866
		75	75	67	66	66	76	80			
1977	117	44373	4709	3428	3406	3405	14903	13849			3181
		110	104	99	97	97	113	115			
1978	101	59609	1833	1833	1811	1811	10849	14048			1689
		118	118	109	108	108	119	120			
1979	114	41918	4331	2045	2036	1063	6802	11580			2162
		78	78	70	67	35	78	81			
1980	106	26518	2361	1012	1007		4943	6585			1400
		45	45	43	43		46	50			
1981	94	20953	1819	929			4218	5048			1303
		37	37	36			37	39			
1982	74	22279	1668	876			3990	6129	419	450	1740
		31	31	31			31	31	2	2	
1983	33								500	498	
									3	3	
1984	30	6300	426	388			1437	1432	85	209	
		11	11	11			11	11	1	2	
1985	48	14114	1015	972			3428	3766	9	19	
		23	23	23			23	23	1	1	
1986	21	9750	709	634			2053	2177	1172	1098	
		20	20	20			20	20	3	3	
1987	17	7427	332	301			1593	1910			
		17	9	8			17	17			

Table 4, cont.: footnotes

[a]CRUISE SPECIFICATIONS RECORDS: includes both NMFS and IATTC cruises: indicate number of cruises during which dolphin sets were observed.

[b]Vessel Activity: from the FISHING MODE RECORD data base.

[c]Set Log records: from the MARINE MAMMAL SET LOG data base and the SCHOOLFISH AND FLOTSAM SET LOG.

[d]Tally Log: from the MARINE MAMMAL SET LOG data base.

[e]Kill Log: from the MARINE MAMMAL SET LOG data base.

[f]Prorated Kill: from the MARINE MAMMAL SET LOG data base.

[g]Mammal Effort: from the MARINE MAMMAL DAILY WATCH EFFORT RECORD.

[h]Mammal Sightings: from the MARINE MAMMAL SIGHTING RECORD.

[i]Research Effort: marine mammal effort records during research cruises on NMFS vessels.

[j]Research Sightings: marine mammal sightings during research cruises on NMFS vessels.

[k]Life History: from the PORPOISE LIFE HISTORY FORM records.

Table 5. Number of Bridge Logs filed by U.S. certified tuna purse-seiners operating in the eastern tropical Pacific Ocean; total number of entries in all filed bridge logs (indicates number of sets on dolphin schools); estimated number of sets on dolphin schools per cruise (entries/bridge log), number of vessels with observers sent either by NMFS or by IATTC; and number of research surveys (shipboard or aerial) by NMFS and IATTC. Numbers are approximate, and will vary depending on the definition used for including a trip in one year or the next, for trips that extend past December 31. Data from Oliver 1983, Porpoise Data Management System, Table 2, unpubl. MS. Point of table is to indicate magnitude of observer effort by each agency, each year.

YEAR	Bridge[a] logs	Brdg. log[b] entries	entries[c] /BL	NMFS[d] observed cruises	IATTC[d] observed cruises	Total observed cruises	NMFS research cruises	IATTC research cruises	NMFS gear cruises	aerial surveys
pre 1971										
1971				5		5			3	
1972				12		12			3	
1973				23		23			3	
1974				41		41	1		2	1
1975	424	7171	17	33		33			2	
1976	431	6933	16	54		54	5		26	
1977	317	6626	21	108		108	6		25	1
1978	275	3878	14	113		113	1		6	
1979	244	6114	25	76	108	2	1		3	1
1980	65	4843	75	44	46	90	4		1	
1981	216	5267	24	58	72	130				1
1982	64	3089	21	40	32	72	1			
1983	64	1550	24	0	30	30	2			
1984	65	1828	28	16	11	27				
1985				23	23	46				
1986				20	20	40	2			
1987							2			1

[a]number of cruises by U.S. certified tuna purse seiners

[b]number of recorded sets involving marine mammals

[c]approximate number of dolphin sets per cruise

[d]number of cruises witnessed by official observers from NMFS or IATTC observer programs

Table 6. Events during specific years that affected the quality or quantity of data collected during cruises by tuna purse seiners or during research surveys by NMFS or IATTC.

1) TUNA CRUISES:

1974: first year tuna seiners required to carry observers; first year vessels chosen by statistical weighting scheme
1975: first year observers accompany seiners on trips outside CYRA; greater detail in records of position, activities, and mortalities
1976: problem with observers recording sighting distance to marine mammals instead of initial cue
1977: fishery left late because of legal problems with dolphin quotas
1983: court order forbids placing NMFS technicians without a search warrant; no NMFS observers go to sea; IATTC observers continue to go to sea
1984: court order remanded; NMFS technicians return to seiners.
1986: dolphin quota reached; fishery closed to dolphin fishing, Oct.
1987: NMFS begins 100% coverage of all US purse-seiners

2) RESEARCH CRUISES:

a) CHARTERS (GEAR, BEHAVIOR):

1971: Queen Mary charters (NMFS); testing Medina panel
1978: Queen Mary charters (NMFS); seining video, PSIS tests, video, tagging, behavior in nets
1979: GINA ANNE with helicopter (IATTC charter, NMFS cooperation); primarily for school-size estimates
1981: NMFS gear program discontinued
1982: NMFS PRE-DOTS experiment: testing biases in aerial surveys

b) ABUNDANCE SURVEYS (SHIP, NMFS):

1974: Jordan(Jan.- March)
1976: Jordan, Cromwell (Jan.- March)
Jordan (Oct.- Nov.)
Surveyor (Nov.- Dec.); with helicopter testing avoidance of ship by dolphin schools (Au and Perryman)

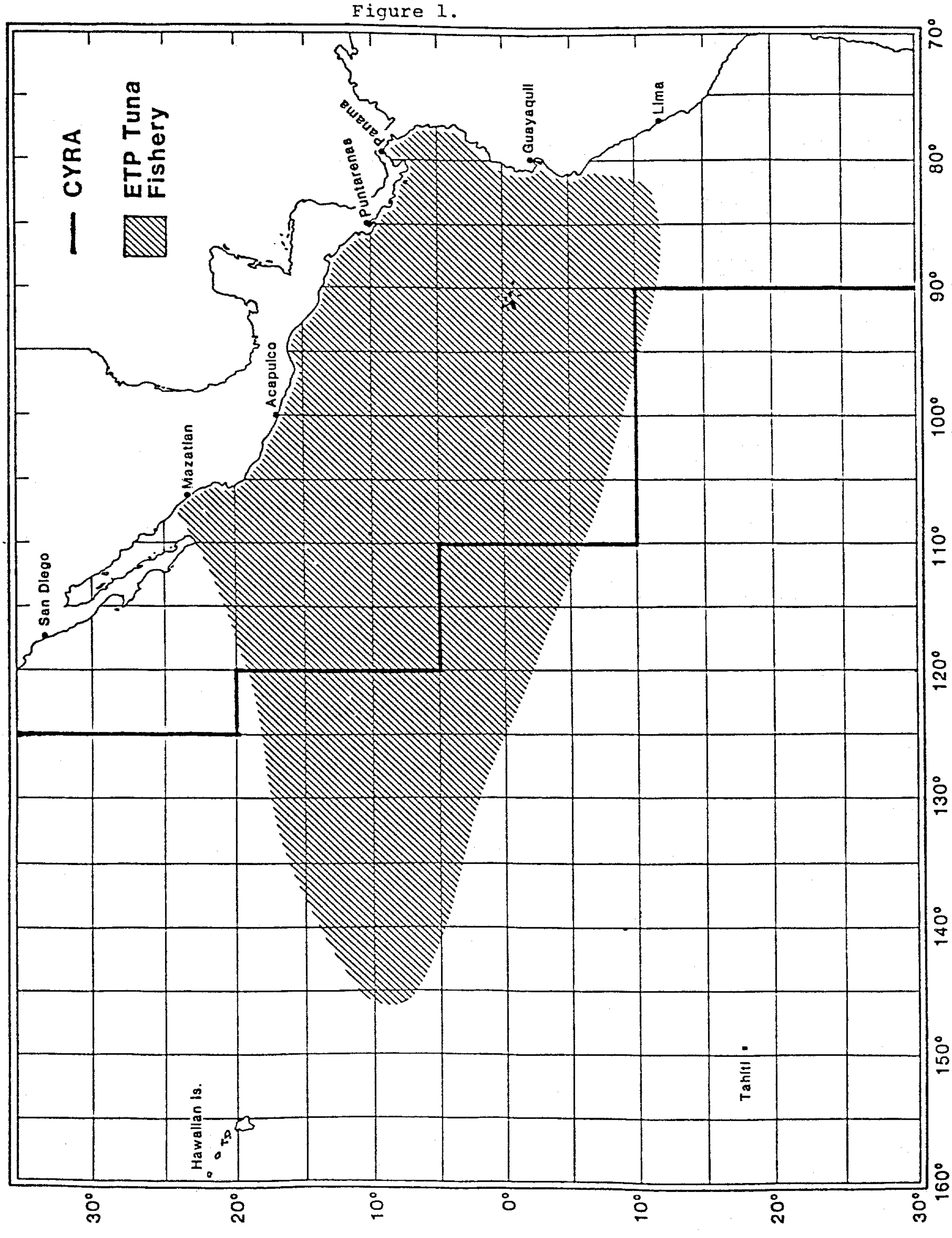
Table 6. (continued)

1977: Jordan, Cromwell (Jan.-Mar.); with Aerial Survey (Feb.-June); Jordan (Oct.-Nov.)
1979: Jordan, Cromwell (Jan.-Mar.); with Aerial Survey (Jan.-May); calibration area surveys
1980: Jordan, Cromwell (Jan.-Mar.); with Aerial Survey (Jan.-May); calibration area surveys
1982: Jordan (May-Aug.); Au and Perryman, ship avoidance
1983: Jordan (Jan.-April)
Surveyor (Mar.-April); with helicopter testing ship avoidance (Hewett)
1986: Jordan, MacArthur (Aug.-Dec.); MOPS1
1987: Jordan, MacArthur (Aug.-Dec.); MOPS2
1988: Jordan, MacArthur (Aug.-Dec.); MOPS3

c) ABUNDANCE SURVEYS (AERIAL, NMFS):

1974: NMFS 1st AERIAL SURVEY
1977: NMFS 2nd AERIAL SURVEY (Feb.-June; Peru-Hawaii)
1979: NMFS 3rd AERIAL SURVEY (Jan.-May; Mex.-Peru)

Figure 1.



CYRA
ETP Tuna Fishery
San Diego
Mazatlan
Acapulco
Puntarenas
Panama
Guayaquil
Lima
Hawaiian Is.
Tahiti
30°
20°
10°
0°
10°
20°
30°
160°
150°
140°
130°
120°
110°
100°
90°
80°
70°

Figure 2. NMFS "Bridge Log" (MARINE MAMMAL LOG SHEET)

SET	DATE AND TIME	POSITION	BEAU-FORT #	SWELL (FT.)	MARINE MAMMALS	STOCK NAME	CHASED	CAUGHT	MORTAL-ITIES	SERIOUS INJURY	TUNA	TONS	BKDN.	MARINE MAMMAL RELEASE PROCEDURES USED & REMARKS
	DATE	LAT.			SPOTTERS						YELLOWFIN		YES	
	TIME	LONG.			SPINNERS						SKIPJACK			
					OTHER						OTHER		NO	
	DATE	LAT.			SPOTTERS						YELLOWFIN		YES	
	TIME	LONG.			SPINNERS						SKIPJACK			
					OTHER						OTHER		NO	
	DATE	LAT.			SPOTTERS						YELLOWFIN		YES	
	TIME	LONG.			SPINNERS						SKIPJACK			
					OTHER						OTHER		NO	
	DATE	LAT.			SPOTTERS						YELLOWFIN		YES	
	TIME	LONG.			SPINNERS						SKIPJACK			
					OTHER						OTHER		NO	
	DATE	LAT.			SPOTTERS						YELLOWFIN		YES	
	TIME	LONG.			SPINNERS						SKIPJACK			
					OTHER						OTHER		NO	
	DATE	LAT.			SPOTTERS						YELLOWFIN		YES	
	TIME	LONG.			SPINNERS						SKIPJACK			
					OTHER						OTHER		NO	
	DATE	LAT.			SPOTTERS						YELLOWFIN		YES	
	TIME	LONG.			SPINNERS						SKIPJACK			
					OTHER						OTHER		NO	
	DATE	LAT.			SPOTTERS						YELLOWFIN		YES	
	TIME	LONG.			SPINNERS						SKIPJACK			
					OTHER						OTHER		NO	
	DATE	LAT.			SPOTTERS						YELLOWFIN		YES	
	TIME	LONG.			SPINNERS						SKIPJACK			
					OTHER						OTHER		NO	
	DATE	LAT.			SPOTTERS						YELLOWFIN		YES	
	TIME	LONG.			SPINNERS						SKIPJACK			
					OTHER						OTHER		NO	

Submit the original and one copy within 48 hours after arrival in port to:

NATIONAL MARINE FISHERIES SERVICE
'B' STREET PIER, ROOM 7
1140 N. HARBOR DRIVE
SAN DIEGO, C   RNIA 92101
Tel: (71   6540

I THE UNDERSIGNED HEREBY DECLARE UNDER PENALTY OF PERJURY THAT THE INFORMATION SUPPLIED IN THIS LOG IS TRUE AND CORRECT.

NOTE: The vessel shall retain one copy of this log for reference.

PRINT NAME OF VESSEL	TRIP DATES	CERTIFICATE NUMBER
		FSW
PRINTED NAME OF VESSEL / FOR	SIGNATURE OF VESSEL OPERATOR	

NMFS-FSW34 12/77

U.S. DEPT. OF COMMERCE

Figure 3. IATTC "SEINER FISHING RECORD AND BRIDGE LOG".

VESSEL ____________ FROM ____________ TOWARD ____________ DATE ____________

TUNA FISHING — RECORD OF SETS MADE

LOCATION	TYPE OF SCHOOL	TIME SET MADE	TIME SET FIN.	CATCH (TONS)				WELLS	PLANE USED	WATER TEMP	REMARKS
				YELLOW-FIN	SKIP-JACK	BLUE-FIN					
		TOTAL TONS TO DATE THIS TRIP									

NAVIGATION, ETC.

NOTES

HOUR	DISTANCE BY LOG OBSERV.	COURSE		WIND		WEATHER	BAROM-ETER	TEMPERATURE		SEA	IMPORTANT: RECORD TAG NUMBER OF TAGGED FISH
		TRUE	COMPASS	DIRECT	FORCE			AIR	WATER		
A.M.											
P.M.											

FISHING RECORD FOR SARDINES, MACKEREL, ETC.

LOCATION	CATCH (TONS)	KIND OF FISH	NO. SETS	REMARKS

Figure 4. NMFS CRUISE SPECIFICATION RECORD

NOAA FORM 88-121
FSW32 10/87

NOAA - U.S. DEPT. OF COMMERCE

CRUISE SPECIFICATIONS RECORD

CRUISE #	CARD #	VESSEL CODE	YEAR BOAT BUILT	FISH CAPACITY (SHORT TONS)	VESSEL CLASS	DATE SAILED YR	MO	DAY	DATE RETURNED YR	MO	DAY	COMPLETED TRIP? Y/N
1	4	6	10	12	16	17	19	21	23	25	27	29
	0 1											

SAILED FROM. ____________________

RETURNED TO. ____________________

OBS #	OBS. TYPE	# TRIPS	#M.M. SETS SEEN	SEQ. #
30	33	35	37	40

(OBSERVER DATA)

TYPE GEAR	#SPDBTS ABOARD	HELICOPTER? Y/N	BOWTHRUSTER? Y/N
43	45	46	47

THE NET

YEAR NET BUILT	NET LENGTH (FM)	NET DEPTH (FM)	NET DEPTH (Strips)	MESH SIZE (In. & 100ths)
49	51	54	57	59

SAFETY PANEL

Y/N	YEAR INSTALLED	PANEL LENGTH (FM)	PANEL DEPTH (FM)	PANEL DEPTH (Strips)	MESH SIZE (In. & 100ths)
62	63	65	68	70	72 (74)

CARD #	VESSEL NAME
0 2	
4	6 – 31

OPERATOR CERTIFICATE HOLDER	CERTIFICATE NUMBER
32	61 – 69

CARD #	VESSEL CERTIFICATE HOLDER	CERTIFICATE NUMBER
0 3	6	35 – 43

Figure 4b.

PORPOISE SAFETY GEAR INSPECTION

Yes=1 No=

1. Net is equipped with porpoise safety panel . . . . ____
2. Safety panel is ≤ 1-1/4" stretched mesh webbing . . . . ____
3. Safety panel is ≥ 2. strips deep (≥ 200 meshes of 4-1/4" stretched mesh webbing) . . . . ____
4. Estimated length of porpoise safety panel (fathoms) . . . . ____
5. Porpoise safety panel protects the perimeter of the backdown area (the perimeter extends from the last bow bunch pulled to 2/3 the distance from the apex to the stern tiedown point) . . . . ____
6. Each end of the porpoise safety panel is identified by a distinguishable marker (markers are balloons or contrasting corks) . . . . ____
7. Throughout the safety panel, handhold openings are secured tightly so that the insertion of a 1-3/8" diameter cylindrical object meets resistance . . . . ____
8. Corkline hangings in the safety panel are secured as in #7 . . . . ____
9. All speedboats are rigged with towing bridles and towlines . . . . ____
10. Vessel is equipped with two facemasks and snorkels, or two viewboxes, and a raft suitable to be used as a porpoise observation and rescue platform . . . . ____
11. Vessel is equipped with lighting system capable of producing 140,000 lumens of output . . . . ____
12. Twenty fathoms at apex free of lines . . . . ____
13. Net is equipped with super apron . . . . ____
14. If super apron is present, apron is marked at both ends . . . . ____
15. Super apron performance problem (if no, disregard a, b, & c below) . . . . ____
    a. Distance from bow ortza to beginning of safety panel . . . . ____
    b. Distance to beginning of apron from end of last bowbunch pulled . . . . ____
    c. Number of bowbunches pulled . . . . ____

Use the schematic corkline below to draw in the location of safety panel, apron, halfnet marker, panel and apron markers.

Figure 5. NMFS FISHING MODE RECORD

NOAA FORM 88-105
FSW32 10/85

NOAA – U.S. DEPT OF COMM.

FISHING MODE RECORD

CRUISE #		DATE YEAR	MONTH	DAY
1	4	7	9	11

TIME OF MODE CHANGE	SEARCHING Y/N	SPEED KTS & 10ths	# 20X	SURFACE TEMP °F & 10ths	BEAU #	FOG/RAIN	[illegible]	CHASE SET Y/N	SET #	SET TYPE	INACTIVE Y/N	CODE
13	17	18	21	22	25	26	27	28	29	32	34	35

NO FOG OR RAIN = 1
FOG = 2
RAIN = 3
FOG AND RAIN = 4

BEAUFORT STAGE
0-1 2-3 4/5+

★ U.S. Government Printing Office: 1987—783-857 60520

Figure 6. NMFS MARINE MAMMAL WATCH DAILY EFFORT RECORD

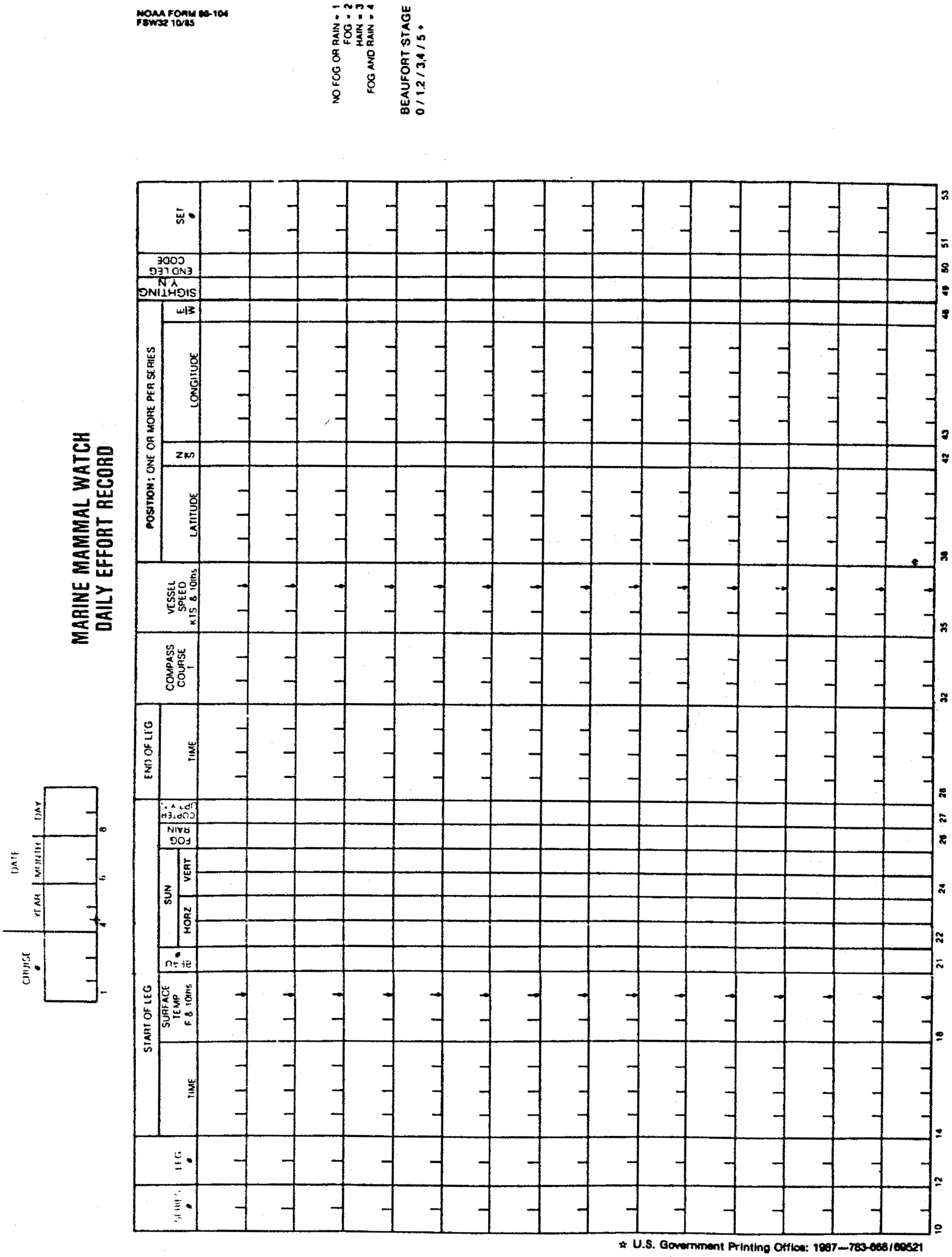


Figure 7. NMFS MARINE MAMMAL SIGHTING RECORD.

NOAA FORM 88-105
FSW32 10/87

NOAA — US DEPT OF COMM

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MARINE MAMMAL SIGHTING RECORD

CRUISE #	DATE YEAR	MONTH	DAY	SIGHT #	SERIES #	LEG #	CARD #
1	4	6	8	10	12	14	0 1 (16)

SIGHTING CUE: TIME	CUE CODE	SIGHT CODE	BEARING FROM SHIP	DISTANCE nmi & 10ths	ENVIR. COND. AT CUE: BEAUF. #	SURF TEMP °F & 10ths	POSITION AT TIME OF CUE: LATITUDE	N S	LONGITUDE	E W	SOURCE CODE	TIME M M SIGHTED	SET #	BIRDS? + -
18	22	23	24	27	30	31	34	38	39	44	45	46	50	53

AVERAGE CREW ESTIMATE OF SCHOOL SIZE: MEAN	HIGHEST	LOWEST
54	58	62

OBSERVER ESTIMATE OF SCHOOL SIZE: BEST	HIGHEST	LOWEST	CARD #
66	70	74	77 0 2 (16)

SOURCE CODES
1 - DR
2 - Verbal
3 - Satellite
4 - Post Cruise

	%	CODE	NAME
SPECIES (1)	18	21	
(2)	28	31	
(3)	38	41	
(4)	48	51	

	%	CODE	NAME
SPECIES (1)	23	26	
(2)	33	36	
(3)	43	46	
(4)	53	56	RC 58

TOTAL TIME OF OBSERVATION	ENVIR COND	CLOSEST DISTANCE OF OBSERVATION	AMT OF TIME AT CLOSEST DISTANCE	TAGS ASSOCIATED	METHOD OF OBSERVATION
59	63	64	66	70	71

METHOD CODES
1 EYE
2 LOW POWER(7X,10X)
3 HIGH POWER(20X,25X)
4 EYE AND LOW
5 EYE AND HIGH
6 LOW AND HIGH
7 EYE, LOW AND HIGH

CUE CODES
1 BIRDS
2 SPLASHES
3 MAMMALS
4 SHIPS
5 OTHER OR UNKNOWN
6 WHALE BLOW

SIGHT CODES
1 CREWMAN ON 20X
2 CREWMAN NOT ON 20X
3 OTHER CREWMAN
4 OBSERVER ON 20X
5 OBSERVER NOT ON 20X
6 OTHER OR UNKNOWN
7 HELICOPTER

BEAUFORT NUMBERS
0 LIKE GLASS
1 RIPPLES
2 WAVELETS
3 OCCASIONAL WH. CAPS
4 FREQUENT WHITE CAPS
5 MANY WHITE CAPS, SOME SPRAY

NARRATIVE: DISCUSS EVENTS DURING THIS SIGHTING

Figure 7b.

NOAA FORM 88-105
FSW32 10/87

NOAA — U.S. DEPT OF COMM

MARINE MAMMAL
SIGHTING RECORD

PAG

SIGHTING SUMMARY

LIST ALL DIAGNOSTIC FEATURES OBSERVED (INCLUDE ESTIMATED BODY LENGTH)

SKETCH FEATURES OF ANIMALS SIGHTED

BEHAVIOR — (DESCRIBE AGGREGATION, MOVEMENT, BOW AND STERN RIDING, BLOWS, ETC.)

☐ SEE SET LOG, PAGE 1

ASSOCIATED ANIMALS — (INCLUDE NUMBER AND SPECIES OF BIRDS)

PHOTOS: ROLL# ________ FRAME(S) # ________

Figure 8. NMFS SCHOOLFISH AND FLOTSAM SET LOG

NOAA FORM 88-122
FSW34 10/87

NOAA — U.S. DEPT OF COMMERCE

SCHOOLFISH AND FLOTSAM SET LOG

SET TYPE
01 SCHOOL FISH
03 NIGHT SET
04 FLOTSAM
05 UNKNOWN
06 WASH NET

FISH CODES
01 ALBACORE
02 BLACK SKIPJACK
03 BULLET MACKEREL
04 MIXED BLACK SKIPJACK & BULLET MACKEREL
05 UNKNOWN
06 BLUEFIN
07 BONITO
08 BIGEYE

CRUISE #	SET #	CARD #	DATE: YEAR	DATE: MONTH	DATE: DAY	POSITION: LATITUDE	N/S	POSITION: LONGITUDE	E/W	SET TYPE
1	4	7 (0 1)	9	11	13	15	19	20	25	26

ENVIRONMENTAL CONDITIONS AT TIME TOWLINE IN

BIRDS? CUE Y/N	BIRDS? ASSOC Y/N	WIND (KTS.)	RELATIVE WIND BEARING	SWELL (FT.)	TIME NET LET GO	TIME RINGS UP	NUMBER BUNCHES
28	29	30	32	35	37	41	45

SACKING UP? Y/N	TIME START	CARD (0 2)	BRAILING? Y/N	TIME START BRAILING	TIME END BRAILING	TIME SET FINISHED	TONS LOADED: TONS YF	TONS LOADED: TONS SK	TONS LOADED: TONS OTHER	OTHER FISH CODE
46	47–50	7	9	10	14	18	22	25	28	31

Answer each question by entering appropriate code: 1 = YES 2= NO

1. Fish loss over corks after rings up? If yes describe below .... Y/N [ ] 33

2. Was any gear modified for non-porpoise fishing? If yes describe below .... Y/N [ ] 34

3. Was a strong current present at any time during this set? .... Y/N [ ] 35

Notes (continue on back) ____________________

Figure 9. NMFS MARINE MAMMAL SET LOG

NOAA FORM 88-124
FSW32 10-85

MARINE MAMMAL SET LOG

NOAA - U.S. DEPT. OF COMM.

Page 1

1. BEGIN SET

CRUISE #	SET #	CARD #	DATE: YEAR	MONTH	DAY	POSITION OF SET: LATITUDE	N/S	LONGITUDE	E/W	SET TYPE	TIME CHASE BEGAN	SPDBTS USED
1	4	7 (0 1)	9	11	13	15	19	20	25	26	28	32

2. CREW ESTIMATES OF NUMBER AND SPECIES COMPOSITION OF ENTIRE SCHOOL BEFORE SET

	TOTAL NUMBER	% SPOTTED	% SPINNER	% OTHER SPECIES (1)	% OTHER SPECIES (2)		
	33	37	40	43	46	OTHER SPECIES STOCK (1): NAME	CODE 49
	51	55	58	61	64	OTHER SPECIES STOCK (2): NAME	CODE 67 68
FISH CAPT ESTIMATE, CARD # 0 2 (7)	9	13	16	19	22	SPINNER STOCK. NAME	

3. OBSERVER ESTIMATE OF NUMBER AND SPECIES COMPOSITION OF ENTIRE SCHOOL BEFORE SET

TOTAL NUMBER (ALL SPECIES) — PERCENT SPECIES COMPOSITION

(TIME OF ESTIMATE)	BEST ESTIMATE	HIGHEST ESTIMATE	LOWEST ESTIMATE	% SPOTTED	% EASTERN SPINNER	% WHITEBELLY SPINNER	% OTHER OR UNID. SPINNER	% OTHER SPECIES (1)	% OTHER SPECIES (2)
	25	29	33	37	40	43	46	49	52

SPOTTED STOCK	CODE	OTHER SPINNER:	CODE	OTHER SPECIES/STOCK (1):	CODE	OTHER SPECIES/STOCK (2)	CODE
	55		57		59		61

4. NOTES: (CONDITIONS, CHASE AND BEHAVIOR BEFORE NET LET GO, i.e., FREE RUNNING, JUMPING, EVASION, ETC.)

1. NET LET GO

TIME NET LET GO	EVADED SET? Y/N	NUMBER	MAJOR SPECIES/STOCK EVADED SET:	CODE
	67	68		72 73

Cont. page 5

2. OBSERVER ESTIMATE OF NUMBER AND SPECIES COMPOSITION OF MARINE MAMMALS AT TIME OF ENCIRCLEMENT

TOTAL NUMBER (ALL SPECIES) — PERCENT SPECIES COMPOSITION

(TIME OF ESTIMATE)	CARD #	BEST ESTIMATE	HIGHEST ESTIMATE	LOWEST ESTIMATE	% SPOTTED	% EASTERN SPINNER	% WHITEBELLY SPINNER	% OTHER OR UNID. SPINNER	% OTHER SPECIES (1)	% OTHER SPECIES (2)
	0 3 (7)	9	13	17	21	24	27	30	33	36

SPOTTED STOCK	CODE	OTHER SPINNER	CODE	OTHER SPECIES STOCK (1):	CODE	OTHER SPECIES STOCK (2)	CODE

Figure 9b.

NOAA FORM 88-124
FSW32 10-85

MARINE MAMMAL SET LOG

CRUISE # ______
SET # ______

NOAA - U.S. DEPT. OF COMM.

TIME	1. ENCIRCLEMENT	TIME	2. RINGS UP

NOTES: ______ NOTES ______

1. CONDITIONS AT TIME TOWLINE IN

WIND (KTS)	RELATIVE WIND BEARING	SWELL (FT)
47	49	52

TIME RINGS UP (54)

2. CONDITIONS AT TIME RINGS BREAK WATER

ESCAPED BEFORE RINGS UP ?

Y/N	NUMBER	MAJOR SPECIES/STOCK:	CODE
58	59		63

1. CREW ESTIMATES OF NUMBER AND SPECIES COMPOSITION OF MARINE MAMMALS CAPTURED

	TOTAL CAUGHT	% SPOTTED	% SPINNER	% OTHER SPECIES (1)	% OTHER SPECIES (2)
	65	69	72	75	78 80
	11	15	18	21	24
FISH CAPT ESTIMATE	29	33	36	39	42

OTHER SPECIES/STOCK (1): NAME ______ CARD # 0 4 (7) CODE (9)

OTHER SPECIES/STOCK (2): NAME ______ CODE (27)

SPINNER STOCK: NAME ______

2. OBSERVER ESTIMATE OF NUMBER AND SPECIES COMPOSITION OF MARINE MAMMALS CAPTURED

TIME OF ESTIMATE	TOTAL CAUGHT (ALL SPECIES) BEST ESTIMATE	HIGHEST ESTIMATE	LOWEST ESTIMATE	PERCENT SPECIES COMPOSITION % SPOTTED	% EASTERN SPINNER	% WHITEBELLY SPINNER	% OTHER OR UNID. SPINNER	% OTHER SPECIES (1)	% OTHER SPECIES (2)
( )	45	49	53	57	60	63	66	69	72

SPOTTED STOCK: ______ CODE (75)
OTHER SPINNER: ______ CODE (77)
OTHER SPECIES STOCK (1): ______ CODE (79 80) CARD # 0 5 (7)
OTHER SPECIES STOCK (2): ______ CODE (9)

3. OBSERVATIONS IN NET (i.e., RAFTING, DIVING, JUMPING, COHESIVENESS, SCHOOL COMPOSITION, GROUPS, ETC.)

Figure 9c.

NOAA FORM 88-124
FSW32 10-85

MARINE MAMMAL SET LOG

CRUISE # ________ NOAA - U.S. DEPT. OF COMM.
SET # ________

1. CONDITIONS PRIOR TO BACKDOWN

MANNED SPDBTS #	SPDBTS TC#? Y/N/NA	NET COLLAPSE? Y/N/NA	KILL DUE TO NET COLLAPSE? Y/N/NA	SPDBTS INFLUENCE MARINE MAMMALS? Y/N/NA	SPDBTS ADJUST BD AREA? Y/N/NA
11	12	13	14	15	16

2. LIVE MARINE MAMMALS RELEASED AND OR ESCAPED PRIOR TO BACKDOWN

RESCUE EFFORT? — Y/N (17); # RESCUERS (18); RAFT? Y/N (20); SPOTLT? Y/N (21); SWIM? Y/N (22); OTHER? Y/N (23)

LIVE RELEASED BEFORE BACKDOWN (24)

ESCAPED AFTER RINGS UP? — Y/N (27); NUMBER (28)

3. NOTES: USE OF SPEEDBOATS

TIME	1. TIEDOWN: BOW BUNCHES, PANEL COVER, APRON POSITION	TIME	2. BACKDOWN: RESCUE EFFORT, MAMMAL INVOLVEMENT

3. BACKDOWN – *IF NO BACKDOWN, ANSWER Y/N BACKDOWN AND THEN GO TO RELEASED AND/OR ESCAPED AFTER BACKDOWN*

BACKDOWN? Y/N	TIME START	# BOW BUNCHES	SUNDOWN? Y/N	LIGHTS? Y/N	PANEL COVER Y/N	TIEDOWN? Y/N/NA	TIME END B.D.	OBSERVERS ESTIMATE OF MARINE MAMMALS RELEASED BECAUSE OF BACKING DOWN. BEST ESTIMATE	HIGHEST ESTIMATE	LOWEST ESTIMATE	FISH LOSS DURING BACKDOWN? Y/N	~TONS	CANOPIES? Y/N	KILL DUE TO CANOPIES? Y/N/NA
31	32	36	37	38	39	40	41	45	49	53	57	58	61	62

4. LIVE MARINE MAMMALS RELEASED BY OTHER METHODS DURING BACKDOWN
DOES NOT INCLUDE THOSE ANIMALS THAT WERE BACKED OUT.

5. WEATHER DURING B.D. — CHOP HEIGHT ____ WIND SPEED ____ SWELL HEIGHT ____

RESCUE EFFORT?

Y/N	# RESCUERS	SPOTLT? Y/N	RAFT? Y/N	FACE MASK? Y/N	SWIMMER? Y/N	OTHER? Y/N	# LIVE HAND RELEASED
63	64	66	67	68	69	70	71

6. NOTES: LIGHTS, RAFT, FACE MASK SWIMMER

5. MARINE MAMMAL BEHAVIOR DURING BACKDOWN SLEEPING, "SWIMMING UPHILL" COHESIVENESS, ETC.

Figure 9d.

NOAA FORM 88-124
FSW32 10-85

MARINE MAMMAL SET LOG

CRUISE # ______

SET # ______

NOAA - U.S. DEPT. OF COMM.

# LIVE IN NET AFTER B.D.	CARD #
	06

1. LIVE MARINE MAMMALS RELEASED AND OR ESCAPED AFTER BACKDOWN
IF NO BACKDOWN OCCURRED, ACCOUNT FOR ALL LIVE ANIMALS RELEASED DURING THE SET IN THIS SECTION. THIS IS A SUMMARY OF ALL LIVE ANIMALS ON THE TALLY SHEET (• AND ⊙). RECORD EXPLICIT NOTES

RAFT RESCUE EFFORT? Y/N | # MEN | # LIVE RELEASED (9, 10, 11)

SPEEDBOAT RESCUE EFFORT? Y/N | # MEN | # LIVE RELEASED (14, 15, 16)

SWIMMER RESCUE EFFORT? Y/N | # MEN | # LIVE RELEASED (19, 20, 21)

OTHER METHOD(S) OF RESCUE EFFORT? Y/N | # MEN | # LIVE RELEASED (24, 25, 26)

TOTAL NUMBER OF RESCUERS AFTER BACKDOWN

RELEASED LIVE OVER DECK? Y/N | NUMBER (31, 32)

ESCAPED? Y/N | NUMBER (35, 36)

2. NOTES: (INCLUDE RESCUER DEPLOYMENT AND HAND REMOVAL)

TIMES

3. TALLY SHEET

RECORD ALL DEAD (\) AND ALL UNDETERMINED STATUS (? AND ⓘ) DURING SET ON TALLY SHEET.
RECORD ALL LIVE (• AND ⊙) THAT OCCUR AFTER BACKDOWN ON TALLY SHEET, AND SUMMARIZE ABOVE.
IF NO BACKDOWN, RECORD ALL ANIMALS ON TALLY SHEET, AND SUMMARIZE LIVE (• AND ○) ABOVE.

	SPOTTED																SPINNERS									OTHER SPECIES 1			OTHER SPECIES 2			
	NEONATE			TWO-TONE			SPECKLED			MOTTLED			ADULT			AGE	EASTERN			WHITEBELLY			UNID.									
	M	F	?	M	F	?	M	F	?	M	F	?	M	F	?	UNK	M	F	?	M	F	?	M	F	?	M	F	?	M	F	?	
DUMPED																																
PROCESSED																																
\																																
○																																
?																																
(?)																																

SPOTTER STOCK: ______ OTHER UNID. SPINNER: ______ ______ OTHER SPECIES 1 ______ OTHER SPECIES 2 ______

Figure 9e.

NOAA FORM 88-124
FSW32 10-85

MARINE MAMMAL SET LOG

CRUISE # ______ NOAA - U.S. DEPT. OF COMM.
SET # ______

TIME	1. AFTER BACKDOWN *NET CONFIGURATION AND RESCUE EFFORT*	TIME	

2. SACK UP THROUGH TONS LOADED

Y/N	TIME START	# LIVE IN NET AT START	SACK RESCUE EFFORT? Y/N	# MEN	# LIVE RELEASED
39	40	44	47	48	49

BRAILING?

Y/N	TIME START	# LIVE IN NET AT START	TIME END
52	53	57	60

FINISH SET TIME (64)

STRONG CURRENT THIS SET? Y/N (68)

TOTAL KNOWN MARINE MAMMAL KILL (ADD ↓) (69)

TOTAL INJURED (73)

TONS YF	TONS SK	CARD #	TONS OTHER	OTHER FISH CODE
75	78	80	0 7 (7)	9	12

3. NOTES: (INCLUDE SACK RELEASE AND BRAILING OBSERVATIONS)

PHYSICAL CAUSES OF MORTALITY

1. DISCUSS MORTALITY & NATURE EXTENT OF INJURIES

Cont. on pg. 31

PERCENTAGE OF ALL MARINE MAMMALS KILLED:

	% SPOTTED KILLED	% SPINNER KILLED	% ALL OTHER KILLED
ENTANGLEMENT	14	17	20
ENTRAPMENT	23	26	29
SACKED-UP	32	35	38
OTHER	41	44	47
UNKNOWN	50	53	56

OTHER SPECIES/STOCK CODE

NAME

Figure 9f.

NOAA FORM 88-124
FSW32 10-85

MARINE MAMMAL SET LOG

CRUISE # ______ NOAA - U.S. DEPT. OF COMM.

SET # ______

1. OPERATIONAL MALFUNCTIONS

EQUIPMENT MALFUNCTIONS?	MALFUNCTIONS DELAY SET?	MARINE MAMMALS IN NET DURING MALFUNCTION?	SET ABORTED?	NET DUMP?
Y/N	Y/N/NA | MINUTES	Y/N/NA	Y/N | TIME	Y/N | TIME
61	62 63	65	67 68	72 73 75

DESCRIBE MALFUNCTION(S) IN ORDER OF OCCURRENCE

	TIME OCCURRED	TIME FIXED	ESTIMATED DELAY IN MINUTES	NOTES (TYPE OF MALFUNCTION, HOW, WHY)
1				
2				
3				
4				

SKIPPER COMMENTS

Figure 9g.

NOAA FORM 88-124
FSW32 10-85

MARINE MAMMAL SET LOG

CRUISE # ______ NOAA - U.S. DEPT. OF COMM.

SET # ______

SYMBOLS

INDICATE TIME AND EVENT
(Operations, Malfunction, Rescue, Net Collapse, Mortality, etc.)

X	PORPOISE
E	ENTANGLEMENT
W←	WIND DIRECTION
D←	CURRENT DIRECTION
C	CANOPY
N	NET COLLAPSE
S	CORKLINE SINKAGE
PSP	PORPOISE SAFETY PANEL
R	PORPOISE RESCUE OR RELEASE
Ø	BOW BUNCH
(S)	SKIFF
▷	SPEEDBOAT
(R)▷	SPEEDBOAT OR TENDER INVOLVED IN HAND RELEASE
(S)	SWIMMERS

- SPEEDBOAT ATTACHED BUT NOT TOWING
- TOWING FROM STERN
- TOWING FROM BOW
- TOWING ONE BUNCH
- TOWING TWO BUNCHES
- TOWING ON CORKLINE
- (R) RAFT
- MANNED SPEEDBOAT

ENTER ADDITIONAL SYMBOLS YOU USE:

TIME

NOTES

TIME

NOTES

TIME

NOTES

TIME

NOTES

TIME

NOTES

Figure 9h.

NOAA FORM 88-124
FSW32 10-85

MARINE MAMMAL SET LOG

CRUISE # ________ NOAA - U.S. DEPT. OF COMM.

SET # ________

NOTES ON THIS SET (NOTE TIMES):

TIMES	

☆ U.S. Government Printing Office: 1987—784-497/69547

Figure 10. NMFS PORPOISE LIFE HISTORY FORM

NOAA FORM 88-129
FSW32 10/87

PORPOISE LIFE HISTORY FORM

NOAA U.S. DEPT. OF COMM.

CARD 1 (12)

CR. # ____ (1–4) SPECIMEN # ____ (5–12)

SPECIES/STOCK ____ (13–14) SEX ____ (15)

DATE (YR/MO/DAY) ____ (16–21) SET # ____ (22–24)

POSITION (LAT/LONG) ____ (25–33) QUAD ____ (34)

TOTAL LENGTH (cm.) ____ (35–38) (SPOTTED ONLY) COLORATION ____ (39)

LACTATING ? ____ (40) FETUS: SEX ____ (41) LENGTH (cm.) ____ (42–45)

COLLECTED ?: TEETH ____ (46) TESTIS ____ (47) OVARIES & UTERUS ____ (48)

FETUS ____ (49) STOMACH ____ (50) HEAD ____ (51) CARCASS ____ (52)

MAMMARY GLAND ____ (53) MILK ____ (54) PARASITES ____ (55) BLOOD ____ (56)

PHOTOS ? ____ (57) ROLL # ____ FRAME(S) # ____

COLOR PATTERN & DORSAL FIN: (SPINNER ONLY)

BASIS FOR STOCK ID.:

____ (OBSERVER'S NAME)

IN FIELD

NOTE: IF FETUS< 25 CM., LEAVE IN UTERUS & PRESERVE (do not sex & measure in field)

IN LAB

CARD 2 (12)

13–19	20–26	27–33	34–40
TOTAL WEIGHT (gm)	L.GONAD w/ epi.(gm)	L.GONAD w/o epi.(gm)	R.GONAD w/epi.(gm)

41–47	48–53	54–56	57	58–63	64	66
R.GONAD w/o epi.(gm)	RIGHT TESTIS	GLG'S	C.	C. DIAMS (mm)	CA(L)	CA(R)

68	71	73	75	77	79
FOLL. DIAM. (mm)	1	2	3	4	5
	C.A. IN LEFT OVARY				

CARD 3 (12)

13	15	17	19	21	23	25	27
6	1	2	3	4	5	6	Total CORP
C.A. IN RIGHT OVARY							

29	32	33–37
TUBULE DIAM (mm)	PREG?	FETUS WEIGHT (gm)

NOTES (Uterus, Etc.):

C.A. diams (mm) by Type

1	2	3	4	5	6

Figure 11. IATTC VESSEL RECORD

VESSEL RECORD

CRUISE INFORMATION

CRUISE NUMBER _ _ _ _

SCIENTIFIC TECHNICIAN ______________________ FISH CAPTAIN ______________________

VESSEL ______________________ CAPTAIN CODE _ _ _ _ IATTC NO. _ _ _ _ TRIP NO. _ _ _ _

FLAG CODE _ _ CAPACITY _ _ _ _ RELATED CRNO'S _ _ _ _ / _ _ _ _ COMPLETED CRUISE? ______

DEPARTURE DATE ____/____/____ DEPARTURE PORT ______________________

ARRIVAL DATE ____/____/____ ARRIVAL PORT ______________________

VESSEL GEAR

NET: LENGTH (FTH) _ _ _ DEPTH (FTH) _ _ _ No. OF STRIPS _ _ MESH SIZE _._ _

SAFETY PANEL SYSTEM ______________________

SAFETY PANEL: LENGTH(FTH) _ _ _ DEPTH(FTH) _ _ _ No. OF STRIPS _ _ MESH SIZE _._ _

No. OF SPEEDBOATS ___ BOW THRUSTER ___ HELICOPTER ___ SONAR ___ RING STRIPPER ___

NO. OF SCREWS (PROPELLORS) ___ POWER BLOCK SIZE (IN.) ___ RAFT ___ HIGH INTENSITY FLOODLIGHT ___ BIRD RADAR ___

DESCRIPTION OF EXPERIMENTAL GEAR ______________________

____

IATTC TUNA-DOLPHIN FORM 1- 1/3/89

Figure 11b. IATTC VESSEL RECORD

NET AND SAFETY PANEL DIMENSIONS

Total Net Length (fathoms)	Tech. Estimate	________	
	Crew Estimate	________	
Total Net Depth	Tech. Estimate	________ (strips)	________ (fathoms)
	Crew Estimate	________ (strips)	________ (fathoms)
Net Mesh Size (inches-stretched)	Tech. Estimate	________	
	Crew Estimate	________	
Safety Panel System	________		
Safety Panel Length (fathoms)	________ est. #1	________ est. #2	________ est. #3
		________ Crew est.	
Safety Panel Depth	Tech. Estimate	________ (strips)	________ (fathoms)
	Crew Estimate	________ (strips)	________ (fathoms)
Safety Panel Mesh Size (inches-stretched)	Tech. Estimate	________	
	Crew Estimate	________	

NET DIAGRAM

Figure 12. IATTC DAILY ACTIVITY RECORD

DAILY ACTIVITY RECORD

CRUISE NO.____ YEAR AND MONTH OF TRIP START ____ PAGE NUMBER ____

DATE	EVENT	ON DUTY?	TIME OF EVENT	TIME MARINE MAMMALS SIGHTED	POSITION AT TIME OF EVENT		NO. 20 X SIGHTING	BEARING FROM SHIP	DISTANCE	SIGHT NO.	VESSEL SPEED	WATER TEMP.	WEATHER			AERIAL ASSISTANCE	SET NO.	CATCH (SHORT TONS)			SPECIES CODE	WELLS
					LATITUDE N/S	LONGITUDE E/W							CLOUD COVER	BEAU. NO.	VISIBILITY			YF	SJ	OTHER		

IATTC Tuna-Porpoise
Form 2 4/80

Figure 13. IATTC MARINE MAMMAL SIGHTING AND SET RECORD

MARINE MAMMAL SIGHTING AND SET RECORD

DATE ________ CRUISE NO. ______ TIME MARINE MAMMALS SIGHTED ______ SIGHTING NO. ______ SET NO. ______ PAGE 1

1. INITIAL ESTIMATE OF NUMBER AND SPECIES COMPOSITION OF ENTIRE SCHOOL

	TOTAL NUMBER	% SPOTTED	% E-SPIN	% WB-SPIN	% UNIDSPIN	% COMMON	% OTHER SPECIES (1)	% OTHER SPECIES (2)	SPOTTED STOCK	OTHER SPECIES/ STOCK (1)	OTHER SPECIES/ STOCK (2)
TECHNICIAN :											
CREW :											
AERIAL :											
									NAME	NAME	NAME

2. CHARACTERISTICS USED TO IDENTIFY MARINE MAMMALS. DESCRIBE CHARACTERISTICS ACTUALLY SEEN AND MAKE A DRAWING OF AN INDIVIDUAL.

CREW'S ESTIMATE

	TOTAL NO.	% COMPOSITION		
1)				
2)				
3)				

INDICATE CLOSEST DISTANCE MAMMALS WERE SIGHTED ______________

IATTC Tuna-Dolphin
Form 3 7/87

Figure 13b.

MARINE MAMMAL SIGHTING AND SET RECORD

PAGE 2

3. MARINE MAMMAL EVASION AND ESCAPE BEHAVIOR

	SCHOOL HERDING CODE	SP. NO. 1 ACTIVITY CODE	NO. ESCAPED, CUT OUT OR EVADED	SP. NO. 2 ACTIVITY CODE	NO. ESCAPED, CUT OUT OR EVADED	SP. NO. 3 ACTIVITY CODE	NO. ESCAPED, CUT OUT OR EVADED	SP. NO. 4 ACTIVITY CODE	NO. ESCAPED, CUT OUT OR EVADED	TOTAL BY SPECIES THAT EVADED, ESCAPED OR WERE CUT OUT
BEFORE CHASE										
DURING CHASE										
DURING ENCIRCLEMENT										
DELIBERATELY CUT OUT										
EVADED UNDER NET										
ESCAPED OVER NET										
									GRAND TOTAL:	

4. CHASE AND SET TIMES

CHASE START	NO. SPBTS	CHASE CALLED OFF	REASON CHASE CALLED OFF	LET GO	REASON SET ABORTED	RINGS UP	BACKDOWN START	BACKDOWN FINISH	SKIFF ABOARD	IF EVENING SET INDICATE TIME OF SUNDOWN
TIME		TIME		TIME		TIME	TIME	TIME	TIME	TIME

5. OBSERVATIONS

a.) DETAILED NOTES ON MARINE MAMMAL EVASION BEHAVIOR DURING CHASE

b.) DESCRIBE MARINE MAMMAL EVASION AND ESCAPE BEHAVIOR DURING ENCIRCLEMENT AND THROUGH REMAINDER OF SET

Figure 13c.

MARINE MAMMAL SIGHTING AND SET RECORD

CRUISE NO. ______ SET NO. ______ PAGE 3

6. ESTIMATE OF NUMBER AND SPECIES COMPOSITION OF CAPTURED MARINE MAMMALS

	TOTAL NUMBER	% SPOTTED	% E-SPIN	% WB-SPIN	% UNIDSPIN	% COMMON	% OTHER (1)	% OTHER (2)	SPOTTED STOCK	OTHER SPECIES 1	OTHER SPECIES 2
TECHNICIAN											
CREW									NAME	NAME	NAME

CREW'S ESTIMATE

	TOTAL	% COMPOSITION		
1.)				
2.)				
3.)				

NEONATES CAPTURED? YES ____ NO ____

7. LIVE MARINE MAMMALS RELEASED AFTER RINGS UP (X = USAGE; M = USAGE WITH MASK)

(a.) PRIOR TO BACKDOWN (IF NO BACKDOWN GO TO ITEM (d.))

METHODS: SPBT, RAFT, SWIM, OFFDECK — NO. RELEASED

(b.) BY BACKING DOWN

NO. BACKED OUT — TONS FISH LOST

(c.) DURING BACKDOWN BY OTHER METHODS (DOESN'T INCLUDE ANIMALS BACKED OUT)

METHODS: SPBT, RAFT, SWIM — NO. RELEASED

NO. OF LIVE MARINE MAMMALS LEFT IN NET AFTER BACKDOWN

(d.) FOLLOWING BACKDOWN TO BEGINNING OF SACKUP OR IF NO BACKDOWN

METHODS: SPBT, RAFT, SWIM, OFFDECK, OTHER — NO. RELEASED

(e.) SACK RESCUE

NO. RELEASED

8. DESCRIBE RESCUE EFFORTS AND BACKDOWN PROCEDURE:

9. BEST ESTIMATE OF NUMBER AND SPECIES COMPOSITION OF ENTIRE SCHOOL

	TOTAL NUMBER	% SPOTTED	% E-SPIN	% WB-SPIN	% UNIDSPIN	% COMMON	% OTHER (1)	% OTHER (2)	SPOTTED STOCK	OTHER SPECIES 1	OTHER SPECIES 2
TECHNICIAN									NAME	NAME	NAME

Figure 13d.

MARINE MAMMAL SIGHTING AND SET RECORD

TALLY SHEET

CRUISE NO. ______ SET NO. ______

PAGE 4

SYMBOLS TO USE:
- √ = DEAD
- ⊕ = INJURED
- ? = STATUS UNDERTERMINED

NOTE: AN "INJURED" PORPOISE IS ONE THAT APPEARS TO HAVE BROKEN BONES, FLIPPERS OR SNOUT, OR SEVERELY TORN FLIPPERS, FIN, OR FLUKES. ANIMALS THAT ARE BLEEDING PROFUSELY ARE TO BE CONSIDERED AS INJURED, BUT DO NOT CONFUSE BLEEDING PROFUSELY WITH SUPERFICIAL NET CUTS.

	SPOTTED																SPINNERS									COMMON DOLPHIN						UNID
	NEONATE			TWO-TONE			SPECKLED			MOTTLED			ADULT			AGE	EASTERN			WHITEBELLY			OTHER OR UNID						OTHER SPECIES			
	M	F	UNK SEX	M	F	UNK SEX	M	F	UNK SEX	M	F	UNK SEX	M	F	UNK SEX	UNK	M	F	UNK SEX	M	F	UNK SEX	M	F	UNK SEX	M	F	UNK SEX	M	F	UNK SEX	
√																																
⊕																																
?																																

Figure 13e.

MARINE MAMMAL SIGHTING AND SET RECORD

CRUISE NO.________ SET NO.________

10. MARINE MAMMAL MORTALITY AND PHYSICAL CAUSES

ENCIRCLED SPECIES/STOCK	TOTAL NUMBER KILLED	PERCENTAGE KILL ACCORDING TO CAUSE			NUMBER KILLED			NUMBER INJURED			UNDE-TER-MINED STATUS
		TANGLED OR ENTRAPPED	DIED IN SACK	OTHER	M	F	UNK SEX	M	F	UNK SEX	
SPOTTED											
SPINNER											
OTHER SP/STK.											
OTHER SP/STK.											
OTHER SP/STK.											

SKETCH DORSAL FIN, VENTRAL HUMP AND COLOR PATTERN OF EACH SPECIES/STOCK KILLED IN SET

SP/STK # 1 ________

SP/STK # 2 ________

SP/STK # 3 ________

DETAIL SPOTTED MORTALITY BY COLOR PATTERN/AGE AND SEX

NEONATE			TWO-TONE			SPECKLED			MOTTLED			ADULT			AGE UNK
M	F	UNK SEX	M	F	UNK SEX	M	F	UNK SEX	M	F	UNK SEX	M	F	UNK SEX	

DESCRIBE AND DISCUSS MORTALITY: ________

Figure 13f.

11.) INDICATE THE NUMBER OF BOW BUNCHES PULLED DURING THIS SET . . . . ____

12.) INDICATE THE NUMBER OF SPEEDBOATS USED TO TOW ON THE NET. . . . . ____

Answer Y = Yes, N = NO
NA = Not Applicable
U = Unknown

13.) DURING BACKDOWN WAS THE APEX OF THE BACKDOWN CHANNEL COVERED BY THE SAFETY PANEL SYSTEM . . . . ____
(DRAW BOUNDARIES OF THE SAFETY PANEL SYSTEM IN YOUR BACKDOWN ILLUSTRATIONS ON PAGES 7 & 8)

14.) WAS A STRONG CURRENT EVIDENT THIS SET?. . . . . ____

15.) DID A NET COLLAPSE OCCUR WITH MARINE MAMMALS IN THE NET? . . . . ____
a.) WERE MAMMALS KILLED AS A RESULT OF NET COLLAPSE? . . . . ____
b.) HOW WAS THE COLLAPSE CLEARED? ______________________________

16.) WERE CANOPIES EVIDENT DURING THIS SET? . . . . ____
a.) WERE MARINE MAMMALS KILLED AS A RESULT OF A CANOPY?. ____
b.) HOW WAS THE CANOPY CLEARED? ______________________________

17.) IF ALL OR PART OF BACKDOWN OCCURRED IN THE DARK, WERE LIGHTS USED BY THE VESSEL TO ILLUMINATE ANY PART OF THE BACKDOWN CHANNEL?. . . . . ____
a.) DESCRIBE THEIR TYPE AND USE ______________________________

18.) DID A MALFUNCTION OCCUR DURING THIS SET?. . . . . ____
a.) DESCRIBE ALL MALFUNCTIONS IN ORDER OF OCCURRENCE

	TIME OCCURRED	TIME FIXED	DELAY IN SET	(DESCRIBE TYPE OF MALFUNCTION, OPINIONS OF CAUSE AND HOW FIXED)	WERE LIVE MARINE MAMMALS IN NET?	MALF. CODE
1						
2						
3						
4						

Figure 13g.

MARINE MAMMAL SIGHTING AND SET RECORD

CRUISE NO.________ SET NO.________ PAGE 7

19. NET CONFIGURATIONS, SET ILLUSTRATIONS

SYMBOLS

X PORPOISE
E ENTANGLEMENT
W WIND DIRECTION
D CURRENT DIRECTION
C CANOPY
S SINKAGE

Ø BOW BUNCH
® RAFT
S SKIFF
SPEEDBOAT

SPEEDBOAT TOWING ON CORKLINE
VESSEL
PORPOISE SAFETY PANEL LOCATION

IF YOU USE OTHER SYMBOLS DRAW AND DEFINE HERE:

TIME	TIME	TIME
NOTES:	NOTES:	NOTES:

TIME	TIME	TIME
NOTES:	NOTES:	NOTES:

Figure 13h.

CRUISE NO. SET NO.

MARINE MAMMAL SIGHTING AND SET RECORD

PAGE 8

19. NET CONFIGURATIONS (CONTINUED)

TIME

NOTES:

TIME

NOTES:

TIME

NOTES:

TIME

NOTES:

TIME

NOTES:

TIME

NOTES:

20. COMMENTS BY THE CAPTAIN REGARDING THIS SET:

Figure 14. IATTC SCHOOLFISH AND FLOTSAM SET RECORD

SCHOOL FISH AND FLOTSAM SET RECORD

Y = Yes N = No
U = Unknown

DATE_______ CRUISE NO.____ SET NO.____ LET GO_____ RINGS UP_____ SKIFF ABOARD_____

WAS A STRONG CURRENT EVIDENT THIS SET? . . . . ____

DID A MALFUNCTION OCCUR THIS SET? . . . . ____

DESCRIBE ALL MALFUNCTIONS IN ORDER OF OCCURRENCE

	TIME OCCURRED	TIME FIXED	DELAY IN SET	(DESCRIBE TYPE OF MALFUNCTION, OPINIONS OF CAUSE, AND HOW FIXED)
1				
2				
3				

DATE_______ CRUISE NO.____ SET NO.____ LET GO_____ RINGS UP_____ SKIFF ABOARD_____

WAS A STRONG CURRENT EVIDENT THIS SET? . . . . ____

DID A MALFUNCTION OCCUR THIS SET? . . . . ____

DESCRIBE ALL MALFUNCTIONS IN ORDER OF OCCURRENCE

	TIME OCCURRED	TIME FIXED	DELAY IN SET	(DESCRIBE TYPE OF MALFUNCTION, OPINIONS OF CAUSE, AND HOW FIXED)
1				
2				
3				

IATTC Tuna Dolphin
Form 4 10/81

Appendix: Summary of TVOD Collections

Table 1. Chronological, annotated summary of data collections from aerial and research vessel platforms, from observed trips on tuna purse seiners, and from gear research charters.

I) TUNA PURSE-SEINER COLLECTIONS:

Year	Collection	Where	Duration
1966	1 trip (Perrin's first cruise)	Inside CYRA	7/1 - 8/11
1967	1 trip (Perrin's second cruise)	No porpise sets	
1968	1 trip (Perrin's third cruise)	Inside CYRA	4/1 - 8/25
1969	Gulf of Guinea (west Africa)	No porpoise sets	7/10 - 8/25
1970	No routine trips observed		
1971	5 trips biased sample of fleet because all boats with volunteers were smaller, older. Observer program voluntary now.	Inside CYRA	12/28/70 - 12/16/71
1972	12 trips	Inside CYRA	1/1 - 4/1
1973	23 trips Barham (1974)	Inside CYRA	1/1 - 12/15
1974	41 trips First year observers required by law; first year boats chosen by weighting scheme (f (vessel) size)); 8 strata	38 in, 3 out	1/1 - 12/21
1975	33 trips Greater detail begun in more records, position and activity records initiated	30 in, 3 out	1/2 - 12/6

Appendix: Summary of TVOD Collections (continued)

I) TUNA PURSE-SEINER COLLECTIONS:

Year	Collection
1976	54 trips Data problems this year because observers recorded radial dist. to first sighting of marine mammals, instead of original sighting, which was usually birds
1977	108 trips
1978	113 trips
1979	108 trips (76 NMFS; 32 IAATC) IATTC observer program begins
1980	90 trips (44; 46)
1981	180 trips (58; 72)
1982	72 trips (40; 32)
1983	30 trips (0; 30) NMFS observer program declared illegal
1984	27 trips (16; 11) NMFS observer program reinstated
1985	46 trips (23; 23)
1986	40 trips (20; 20) Fishery closed in Oct
1987	NMFS begins 100% coverage on U.S. fleet
1988	100% coverage of fleet continues

Appendix: Summary of TVOD collections (continued)

II) RESEARCH VESSEL COLLECTIONS:

A) CHARTERS: (gear trials, behavior, tagging; from data management group)

Year	Collection	Where	Duration
1970	Perrin		12/22 - 12/22
1971	3 trips (e.g., Queen Mary: test of Medina panel)	Inside CYRA	1-30 day trips
1972	3 trips	Inside CYRA	6 days, 30 days
1973	3 trips	Inside CYRA	All about 3 weeks
1974	2 trips experimental gear	Inside CYRA	
1975	2 trips experimental gear	Inside CYRA	
1976	26 trips	15 inside, 11 outside	
1977	26 trips	3 in, 18 mix 4 outside	
1978	6 trips 5 charter, 1 gear, 5 cruises on dedicated vessel chartered by industry (Queen Mary)	1 inside, 4 mix 1 outside	
1979	3 gear charters: IATTC charters of Gina Anne	Inside CYRA	
1980	1 gear charter: IATTC charters airplane	Mixed	
1981	no charters; gear program ended 1981		

Appendix: Summary of TVOD Collections (continued)

B) ABUNDANCE SURVEYS (ship and aerial); does not include ships of opportunity

Year	Collection	Where	Duration
1974	1 ETP cruise	Jordan; mixed	1/2 - 3/4
	aerial survey (NMFS		
1975	1 ETP cruise		
	Russian vessel; not NMFS (see Perrin files: Feb - April 1976		
1976	5 ETP cruises	Mixed	
	Cromwell		1/5 - 3/3
	Jordan		1/5 - 3/2
	Jordan	Inside	10/5 - 11/18
	Survey (with helicopter)		11/16 - 12/9
	Au and Perryman, 1982		
1977	6 ETP cruises; 1 aerial survey		
	Jordan	Mixed	1/4 - 3/8
	Cromwell	Outside	1/6 - 3/25
	Aerial survey: Lima	From Hawaii	Feb - June
	Jordan	Mixed	10/3 - 11/21
1978	1 ETP cruise	Outside	1/22 - 5/13
1979	2 ETP cruises, 1 aerial survey		
	Jordan	Mixed	1/3 - 3/10
	Cromwell	Mixed	1/3 - 3/16
	3rd aerial survey (NMFS) with Jordan and Cromwell		
1980	4 ETP cruises		
	Jordan	Mixed	1/3 - 3/5
	Cromwell	Mixed	1/3 - 3/6
1981	0 ETP cruises		
1982	1 ETP cruise	Mixed	5/13 - 8/3
	Jordan		

Appendix: Summary of TVOD Collections (continued)

Year	Collection	Where	Duration
1983	2 ETP cruises		
	Jordan		1/12 - 4/13
	Surveyer (with Helicopter)		3/7 - 4/11
1984	0 ETP cruises		
1985	0 ETP cruises		
1986	2 ETP cruises: first of 5-year survey		
	Jordan	Mixed	7/30 - 12/5
	McArthur	Mixed	7/30 - 12/6
1987	2 ETP cruises: second of 5-year survey		
	Jordan	Mixed	7/30 - 12/5
	McArthur	Mixed	7/30 - 12/6
1988	2 ETP cruises: third of 5-year survey		
	Jordan	Mixed	7/30 - 12/5
	McArthur	Mixed	7/30 - 12/5

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(June 1988)

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S.V. RALSTON and H.A. WILLIAMS
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114 Report of ecosystem studies conducted during the 1987 eastern tropical Pacific dolphin survey on the research vessel *McArthur*.
V.G. THAYER, S.B. REILLY, P.C. FIEDLER, C.W. OLIVER and D.W. BEHRINGER
(June 1988)

115 Report of ecosystem studies conducted during the 1987 eastern tropical Pacific dolphin survey on the research vessel *David Starr Jordan*.
V.G. THAYER, S.B. REILLY, P.C. FIEDLER, R.L. PITMAN, G.G. THOMAS and D.W. BEHRINGER
(June 1988)

116 Report of a marine mammal survey of the eastern tropical Pacific aboard the research vessel *McArthur*, July 30-December 10, 1987.
R.S. HOLT and A. JACKSON
(July 1988)

117 Report of a marine mammal survey of the eastern tropical Pacific aboard the research vessel *David Starr Jordan,* August 8-December 10, 1987.
R.S. HOLT and S.N. SEXTON
(July 1988)

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T.C. JOHANOS and S.L. AUSTIN
(July 1988)

119 Hawaiian monk seal and green turtle research on Lisianski Island, 1986.
R.L. WESTLAKE and P.J. SIEPMANN
(August 1988)

120 Hawaiian monk seal and green turtle research on Lisianski Island, 1984 and 1985.
D.J. ALCORN, R.G. FORSYTH and R.L. WESTLAKE
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121 Hawaiian monk seal and green turtle research on Lisianski Island, 1987.
T.S. JOHANOS and R.P. WITHROW
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