BD.15

BEHAVIORAL AND PHYSIOLOGICAL PROPERTIES OF TUNAS AND THEIR EFFECTS ON VULNERABILITY TO FISHING GEAR

Caps

I~~ntroduction~~

A significant void in the present management procedures for ~~in~~ tuna fisheries is in the application of biological information about the various tuna species and their behavioral and physiological responses to the physical environment. As these data sift into the archives slowly and discontinuously, they are often ignored as inputs into the various management schemes. The primary assumption in the present population dynamics estimation methodologies is that the fish and effort are randomly distributed with respect to one another, and within the prey population's habitat. This is, of course, an abiological assumption, in that it is difficult to find any single example of this phenomenon in any biological system, and certainly with men at the helm, the effort cannot possibly be random with respect to anything, particularly their prey species.

The tendency for tunas to school and for schools to aggregate precludes the assumption of randomness in these species. The cyclic patterns in seasonal variation in the physical oceanographic features certainly is responsible for the marked [illegible] aggregations and exploitation of tunas and tuna-like species. One can easily see that if the tunas were truly uniformly and randomly dispersed in their habitat ~~that~~ they would be so rarely encountered as to be virtually non-existant. For example, in the eastern tropical Pacific Sharp and Francis (1976) estimated that the minimum unexploited yellowfin population density was approximately 35.4 mg yellowfin per square meter of ocean surface in the Commission Yellowfin Regulatory Area (CYRA). Given that the average yellowfin in the population probably weighs about 10 kg, then there would be one yellowfin ~~of~~ 10 kg for every 2.83 km^2 of ocean, not a very productive situation considering the cost of searching out and catching that individual.

If one is expected to meaningfully assess the exploitable tuna resource the effects of environmental variables on vulnerability or availability of tunas need to be thoroughly evaluated. One of the major hindrances to this goal is the paucity of environmental data on a realistic temporal and areal basis. The use of long term average data do not result in adequate resolution requisite to meaningful or realistic analyses of the relations between the environment and the behavioral responses of the basic units of exploitation, namely tuna schools or individuals.

Published studies which relate environmental parameters to fishing success are not abundant, but are important to examine with respect to the tuna fisheries and tuna behavior.

Green (1967) showed rather conclusively that there was a greater success in purse seining (58.5% as compared with 42.3% successful sets) where the top of the thermocline did not exceed 60 feet in the eastern Pacific yellowfin tuna (Thunnus albacares) fishery. A concurrent observation was that the success rate was greater (55.5% compared to 45.1%) where the mean temperature gradient within the thermocline was sharpest (>0.55°C/m) than where it was more gradual. Green concluded that the ffects were additive because there appeared to be no significant interaction between them. The combination of sharp gradient and deep thermocline gave the highest success rate (63.9%) and the gradual deep thermocline structure yielded 39.9% successful sets. Green (1969) also refers to the probable effect of limited oxygen on fish distribution, though no data were examined.

The relative success as measured by catch per successful set is an important factor in the interpretation of the effects of vertical thermal structure on tuna vulnerability. This factor has not been discussed in previous studies of purse seining success. Another factor of potential importance is related to the time of day at which purse seine sets are made. Each of these phenomena will be evaluated in turn in the following discussion.

Another major interaction which is of interest is that between the vertical thermal structure and longline fishing success. This method of fishing is less directed in many ways, but particularly with respect to species. A single tropical (20°N to 20°S) longline set may catch as many as ten species including four tunas and <u>Katsuwonus</u> <u>pelamis</u>, as well as 5 billfishes species. Multi-species catches are typical of this gear, whereas surface gear tends toward one or two species in any area. The interesting aspect of this phenomenon is that different areas yield different proportions of each species depending upon season, thermal structure and fishing depth. Studies by Saito (1973) and Saito and Sasaki (1974) utilizing vertical longline gear indicate a vertical stratification of the species in the water column, as well as some phenomenal availabilities at depths far greater than those fished using ~~typical~~ traditional longline methods.

Other studies, such as that by Hanamoto (1975), indicate limitations on catch success in longline fishing activities are correlated with oxygen levels at typical fishing depths. This parameter will also be examined with respect to individual species characteristics in a separate section of this discussion.

As is obvious from the diversity of the material to be covered, what is intended is a summary of pilot studies which, I believe, indicate the significance and need for comprehensive studies of environmental variation and subsequent effects on fishing success. Fishing success is measureable in many ways, and efforts to examine the interactions between environmental parameters and fish vulnerability must include some attempts at examining the fundamental units of exploitation ~~other~~ rather than just seasonal body counts or biomass estimates. Size and age specific fish behavior, distribution, and stratification yield significantly different interactions. Expectation is such that unless they are accounted for, few cause-and-effect relations will be apparent. This means, of course, that one must examine the size and species specific behavioral variation with respect to the environment on a real-time basis. This will require at sea remote sensing studies of the various species, and size or behavioral classes within species.

¶ In the following section an extension of Green's (1967) study ~~was made~~ is presented which was designed to investigate the changes in size (yield) of successful sets as a function of time of day; depth of the mixed layer; the depth of the 23°C isotherm; and the 15°C isotherm. The 23°C isotherm was selected because it approximates the cold water bounds of the distribution of surface yellowfin schools. The 15°C isotherm was chosen because it represents the average or typical lower limit of thermocline in the eastern Pacific Ocean. The temperature realm below 15°C tends to be a constantly declining value, whereas above 15°C the rate of change of temperature may vary dramatically to the top of the thermocline.

double space

Caps

Vulnerability of yellowfin tuna (Thunnus albacares) to purse seine fishing methods

The unique requirement of this study is that one assumes that immigration and emigration have little effect on the parameters being examined. This implies relatively short term - finite area limitations. The other important requirements are that the type of fishing mode be known (e.g. porpoise associated or school fish (see Scott, 1969)), and large numbers of sets exist in each time period to be contrasted due to the skewed distribution of the yields from successful sets (see Figure A). Length frequency estimates are also requisite to interpretation of the phenomena so that one may estimate the numbers of individuals in a captured school.

In the early portion of the 1973 fishing year, large areas of diffusely distributed aggregations of small (less than 70 cm) yellowfin were reported in the area of the Panama Bight. Few schools were sighted in the area which were in a fishable con- ~~formation~~ figuration so that although a large aggregation was located and reported, little catch was made in the area. The onset of good catches in the area was sudden, occurring in about the second week of March. The catch rate then rose consistently through May.

These small yellowfin which occurred off the coasts of Colombia, Panama, and Costa Rica in 1973 ultimately produced the largest catch in numbers on record from a single group of recruits in so limited a time and so small an area. Estimates range from 35 to 46 thousand tons for the yield from this localized group of fish. These events provided the necessary setting for the following studies.

When the 1973 logbook data were available a summarized array was made of the data from all logged sets which included set yield in tons, time of day of the set, location and fishing mode. This array was subsequently distilled into the several separate analyses which will be discussed. The analyses which are the subject of the first discussion are limited to areas 5 and 6 (see figure) due to the limitations imposed by our market sampling (length frequency) program and its importance to the analyses.

keep separate

(~~Tables 1 to 5 show the basic data analyzed for this study.~~) Tables 1 and 2 summarize the basic data which were available for the study area with the requisite time of day information for the analysis. These data are presumed to be slightly more reliable in general than those without this data and form the basis for all of the analyses in the 1973 study period.

Notice that from March 1st to May 30 556 porpoise associated sets averaging 19.93/set and 1382 school sets averaging 11.95 tons/set were recorded. In the two previous months only 256 porpoise sets were logged in the six major 5° squares yielding an average of 9.3 tons per set and only 54 school fish sets were made yielding an average of 3.4 tons per set. Both fishing types yielded less than half the catch per set of the productive period which was selected for examination of the effects of time of day on fishing success.

A significant difference between the school fish and porpoise associated data is that at no time are the porpoise set yields from the study area less than the school fish yields. There are two or perhaps three inter-related phenomena which contribute to this disparity. Primarily there is a distinct difference in the size composition of the yellowfin sets in the two modes of fishing. For example in April 1973, the study area porpoise associated catch was analysed and the average weight of fish in the catch was slightly greater than 46 pounds, whereas the school fish averaged a bit more than 10 pounds. On the average, porpoise associated fish tend to be larger and a greater variance about the mean size of fish is observed than in school fish. A perhaps significant stratification I did not make in the following analyses was the separation of true fish schools from flotsam associated schools. Recent analyses by Greenblatt (personal communication) indicate that the size variance about the mean size increases from small (mean length <70 cm) schoolfish sets, to flotsom (log) associated sets, to the porpoise associated sets where the variance is extremely ~~variable~~ high on a per set basis. Also one can infer from the January-February catches of school fish that there appears to be a primary or core school size for yellowfin of about 3 tons, or about 400-600 individuals per school. From the genetic sample data in the eastern Pacific yellowfin and the Pacific-wide skipjack there is evidence for a cohesiveness of related fishes in schools. What is observed is that the very rare alleles (expected occurrence <.01) are clumped in samples ~~with~~ where more than one is present, such that the individuals exhibiting the rare alleles are often the same length or within 1 cm of each other, which is highly unlikely, to say the least, unless they are related. See Figures __ a and __ b for examples of rare phenotype distributions in tuna schools.

This means , of course, that schools of sizes greater than three tons are very likely to be aggregates of primary schools. In non-porpoise or non-flotsam associated schools the aggregates tend to be of similar size individuals and it can be reasonably assumed that this is due to swimming speed dynamics and energetic considerations. The flotsam associated schools are slightly more size variable than the swimming schools as would be expected from a collection of core schools of variable size passing through a volume of water and responding to the aggregation influence of the relatively stationary object. The porpoise aggregation offers two major enticements above and beyond ordinary flotsam, one is mobility and the other is the size of individual porpoises. The fact that the tunas associated with porpoises are so much larger on the average than the flotsam aggregated fish indicates that there is some differential which selectively aggregates the older, larger yellowfin. That the porpoise schools are not stationary probably accounts for some of the observed length heterogeneity characteristic of yellowfin associated with them. The lack of dependence upon passive aggregation in the sense of movement of the tuna with respect to a stationary object and the obvious possibility that the porpoise herds themselves are built around core units and comprise variable numbers of these units probably accounts for most of the variability in both size and numbers of tunas associated with porpoise herds.

CATCH PER SUCCESSFUL SET AND TIME OF DAY

Porpoise associated schools:

Considering the previous discussion of the probable nature of tuna school and porpoise herd stability I am confident that given adequate information to work with, one can begin to point out the dynamic nature of the tuna-porpoise bond. In the following discussion I will examine the effects of time of day on the yield of yellowfin from porpoise associated sets over a six week period starting March 1 and ending May 30, 1973 in the five (5) degree squares 0-05-75; 0-05-80; 0-05-85; 0-05-90; 0-10-80 (see Figure).

The data clearly show temporal differences in yield per successful set (YPSS) in March which indicate that morning sets (0600-0859) are less productive than P.M. sets (1200-1459). The A.M. sets (0900-1159) and evening sets (1500 to sunset) are intermediate in yield, but different from the low and high periods by about 3 tons per set or a deficit of about one hypothesized primary core school.

The data from early April (1-15) indicate a peak in the A.M. yields of about six tons or nearly two core schools in excess of the yields for the rest of the day, with the four time of day classes for the period yielding an average increase of 5.5 tons over the corresponding data for March, an average difference of about 2 core schools per set. The late April (16-30) and May data are too sparse to treat separately, but show an overall decline in YPSS in comparison to the first six week period. An interesting phenomenon is the stability of the P.M. YPSS value centering about 22.3 tons, ~~and~~ when the entire period is averaged yielding the highest overall value

From this I would infer that the P.M. porpoise herds obtain maximum size, assuming that they are not stable aggregates, and hence maximum recruitment of yellowfin core schools to fishable porpoise herds is observed during this period.

Were it possible to obtain estimates of porpoise herd sizes a great deal more could be learned from similar exercises. The importance of this multiple aggregation phenomenon, as well as the information on recruitment rates of yellowfin core schools to the porpoise aggregations is paramount to a realistic evaluation of catch per unit of effort as well as the assessment of population status of either species group. Further study of these phenomena is necessary to true "management" of the resource.

Non-porpoise associated yellowfin:

The school fish data for the March and early April time periods do not show any dynamic changes in average yield. They center about 10 tons per set or approximately 3 core school units each. The late catch April data shows a jump upward in all classes of about 3 tons, except the A.M. period were 18.6 tons or six core units comprise the average set. The May period averages six tons more per set than the first six weeks, with a peak in the YPSS data occurring in the P.M. set of nearly 23 tons or slightly more than four core units higher yield than the lower average data in the first six week period (10 tons). No systematic or characteristic high yield period is found in this data as was observed in the porpoise associated catches.

The catch per days fishing values (CPUE) for these periods represent the catch per successful set values multiplied by the number of sets made per day and successful set ratios in the various modes of fishing. The estimation of the CPUE was provided by R.C. Francis and are listed in Table . The minimum number of sets made per day is also indicated.

Catch per Unit of Effort and ~~the~~ Thermal Profiles

A ~~compilation of the single-set data was made from logbook abstracts of trips for which effort in the study area was recorded~~. The~~se~~ previously discribed data and the length-frequency data from this time-area stratum were used to estimate the number of fish per set and tons per set caught from non-porpoise associated and porpoise associated schools. These estimates are as follows.

For the non-porpoise associated sets both the number of fish per set and the number of sets per day increased during the period of March 1 to May 31. A large amount of non-porpoise effort occurred during those three months, and it is difficult to explain the increases on the basis of improved vessel efficiency such as gear handling or other fishing techniques. Since environmental factors may influence the catchability of the fish, the available physical oceanographic data (temperature, mixed layer depth, thermocline gradient strength, etc.) were examined with respect to the catch and effort data.

The monthly average depths of the mixed-layer and the 23°C (73.4°F) and 15°C (59.0°F) isotherm depths are plotted in Figure — for the period of January to June. The approximate minimum and maximum depths of a 40-fathom purse seine are shown also. The numbers of fish caught per day and per set for porpoise-associated (P-fish) and non-porpoise-associated (non-P fish) schools in this area are indicated in the figure and in Table — .

The original intent of this study was to examine effect on schooling behavior in tunas. However, the results also yielded important fishery information.

The mixed-layer depth is consistently above the minimum depth, and appears to be unrelated to the increased vulnerability of non-porpoise associated yellowfin. The 23°C isotherm emerges to a depth above the minimum net depth just prior to the [illegible] increase in vulnerability of the fish. This isotherm was chosen a priori due to the observation that small yellowfin (40–70 cm) are found to aggregate at the interfaces of currents which meet, and are available where the sea surface temperature is 23°C and above, but rarely below 23°C, indicating an aversion to temperature less than 23°C. It appears that the smaller yellowfin are more sensitive to colder-than-optimal environments than are the larger fish which comprise the porpoise associated catch. This probably relates to both heat production and heat dissipation rates, which would be expected to vary with size. The energetic considerations are not clear at this time, but models are being created and answers sought.

In the eastern Pacific the 23°C isotherm approximates the mid-point of the thermocline, and the 15°C isotherm the bottom. The plots of the isotherm depths and time of year (Figure —) indicate that both the 15°C and 23°C isotherms may affect the vulnerability of yellowfin during the study period. The 15°C isotherm rises and crosses the maximum depth of the 40-fathom purse-seine fishing depth simultaneously with the 23°C isotherm crossing of the minimum fishing depth.

A regression analysis of the following data was made to determine any correlative effects between the depth of the 23°C isotherm and catch per unit of effort on the two school types (porpoise-associated and non-porpoise-associated) in the study area by month. The porpoise-associated catch per unit of effort (on somewhat larger fish) apparently was not significantly related to the 23°C isotherm depth. The non-porpoise-associated catch per unit of effort was found to be highly correlated with the 23°C isotherm depth. Recent examination... *

In attempting to describe the interaction between small non-porpoise-associated yellowfin and the 23°C isotherm, it appears that the relative depth of the "acceptable" region of water may determine their schooling behavior. The diffuse quality ascribed by the fish-

* of purse seine success and environmental characteristics for data which was accompanied by concomitant XBT data indicate that there is a general fit of the porpoise associated catch success to the parameters examined in this study (Evans and Miller, M.S.

ermen's reports to the distribution of yellowfin in the study area during late January and February was in contrast to the increased aggregation (in both number and tonnage) encountered as the 1973 season progressed. This does not preclude the additional effects of immigration, which may have further affected the density of the fish, but the close relation between fishing success and depth of the 23°C isotherm does not require other external events to cause the observed effects.

During the 1974 fishing season, in an extensive coastal area which includes the 1973 study area, similar environmental assessments were made. During January through June 1974 the 23°C isotherm was consistently above the minimum fishing depth of the typical purse seine net (150 feet). The general density did not appear to be as great due to the much larger area fished in 1974, but the number of fish was so much greater that far more recruit fish (in numbers and tonnage) were caught in 1974 than in 1973. These observations likely represent an important principle in vulnerability of tuna to purse seine and surface gear.

Cap. →

Relative Respiratory requirements of Tunas and their Limiting Effects

A further study of the oxygen requirements of tunas based on swimming energetics at their respective minimum sustained speeds for maintaining hydrodynamic equilibrium yielded the following interesting picture. Table & Exp.

The results for bigeye and albacore will be of interest to the longline fisheries people in particular. From the studies of Hanamoto there exist data indicating that when the oxygen levels at 100 meters are below 1 ml O_2/L H_2O there is a marked decrease in catch success for bigeye. In those areas where bigeye and albacore have overlapping distributions it is likely that as depth increases and oxygen levels decrease, the albacore become excluded by oxygen levels well before bigeye, and that even though temperatures may be within the tolerance range of the albacore, they will not be present. The studies of Saito (1973) in the southern Pacific Ocean which indicate the increasing bigeye concentrations at depths where albacore catch rates have declined may be an indication of this phenomenon. ★ Table & explanation to be added here.

The skipjack requirements may explain the size distribution disparity in the eastern Pacific Ocean which is characterized by the exclusion of the larger skipjack from the warmer coastal zone off Mexico and offshore to below the Revillagigedo Islands. This zone is characterized by the shallow oxygen minimum where level below 1 ml/L are found from 50 to 100 feet. This will be explored further in a later discussion of skipjack.

Yellowfin, of course exhibit both oxygen level sensitivity and temperature affinities which keep them confined pretty well to the upper 100 or so meters of the eastern Pacific Ocean, and only slightly deeper in the majority of the world ocean, more fish (in numbers and tonnage) were caught in 1974 than in 1973.

A further study of the oxygen requirements of tunas based on swimming energetics at their respective minimum sustained speeds for maintaining hydrodynamic equilibrium yielded the following interesting picture:

Species	Fork length	Estimated lower O_2 tolerance (ml O_2/L H_2O)
K. pelamis	50	2.45
	75	3.42
T. albacares	50	1.59
	75	2.06
T. obesus	50	0.74
	75	1.35
T. alalunga	50	1.76
	75	2.25

The results for bigeye and albacore will be of interest to the long-line fisheries people in particular. From the studies of Hanamoto there exist data indicating that when the oxygen levels at 100 meters are below 1 ml O_2/L H_2O there is a marked decrease in catch success for bigeye. In those areas where bigeye and albacore have overlapping distributions

In a sense, the vulnerability of yellowfin to surface and subsurface fisheries can be explained in terms of the environmental profiles of temperature data alone for the Pacific Ocean, where the optimum fishing zone for surface fishing success can be described as an area where the 23°C isotherm lies within 50 m of the surface and the 15°C isotherm is at 80 m. Some variance is expected in yield per successful set as a function of the density of the underlying population of yellowfin and the age structure of the schools. The larger fish should be slightly more independent of the short term environmental temperature variation (minutes) than are the small yellowfin (<70 cm) due to their thermal mass and the subsequent inertial stasis (Neill an- Stevens, 1974), and they may be considerably more tolerant of lower oxygen values due to their potentially lower swimming speed and energy requirements. The traditional longline method exploits the water column down to about 100 m over a distance of more than 50 km such that a relatively large volume of water can be sampled by this gear. Where the hooks pass through the yellowfin habitat into cooler, more anoxic water, the hooks may be taken by bigeye tuna or billfishes. In zones of adequate or high oxygenation (> 2 mil /L) but where the hooks hang in water of 15 to 18°C the catch may comprised of skipjack, albacore, yellowfin, bigeye and billfishes. Catches of this sort characterize certain areas of the central and western Pacific Ocean.

The yellowfin habitat very likely exceeds the 23°C boundary conditions I have placed on them, but as an indicator of abundances and vulnerability, this single parameter contrasted with the depth of the 15°C isotherm should provide information specifically applicable to predicting regions of potential success of surface gear. A compilation of the Pacific wide oceanographic profiles was made so as to provide the following figures which show, on a monthly basis, those areas of the Pacific Ocean which, on the average, exhibit the requisite characteristics for optimum yellowfin school vulnerability as measured by eastern tropical surface fishery behavior. The 23°C isotherm surface emergence is shown as the heavy line at the northern and southern extremes of the range. The range is indicated by the vertical hatching where the 15°C isotherm is shoaler than 80 m is indicated by the cross hatched zones. These indicate the areas where purse seine effort should be maximally successful given the presence of schools of yellowfin. (these are being processed now).

The dependence of this very efficient gear type on aggregating devices for maximum productivity is well known. Experience shows that the only catch by this type of gear outside of the portrayed zones depends upon use of effective aggregating devices (e.g. vertically suspended trees, logs or other flotsam). Far more effort should be expended upon developing an information base for devising, deploying, and harvesting fish from artificial or ship deployed aggregating gear. The use of this gear in the areas of optimum vulnerability of specific tunas would certainly provide greater access to and yields from presently unexploited tuna. Development of these techniques in zones without these optimized environmental profiles would make available portions of populations which are at present not only unexploitable, but unaccountable in our present CPUE based population assessments. A very significant potential is obvious.

TABLE 1

% OF TOTAL SUCCESSFUL SETS IN CLASS

1973 LOGGED SCHOOLFISH DATA WITH TIME AND AREA

TIME	# SETS	0-10	20	30	40	50	60	70	80	100	100
March 1-31											
0600-0859	68	74	13	6	3	1	3				
0900-1159	108	76	15	5	4	t		t			
1200-1459	84	76	14	4	5				t		
1500-Sundown	87	72	22	2	1		2				
	Σ349	74	16	4	10	2	4	t	t		1
April 1-15											
0600-0855	125	70	20	7	1	1	t		t		t
0900-1159	134	75	28	1			1				
1200-1459	140	62	27	7	2	1					
15-Sundown	134	71	20	3	2	1	1	2		1	
	Σ533	68	24	4	1	1	1	1	t	t	t
April 16-30											
0600-0859	54	61	20	7	4	6		2			
0700-1159	77	56	25	3	3	1	4	4	1	1	1
1700-1459	77	60	18	12	6	1	1	1			
1500-Sundown	76	66	14	12	3		3	1			1
	Σ284	61	19	8	4	2	2	2	t	t	1
May 1-30											
0600-0859	38	50	18	11	8			3		3	8
0900-1159	64	66	20	5	2	2	2	2	3		
1200-1459	52	48	19	8	8	5	2	4			6
1500-Sundown	61	57	29	8	2	2	3	3		2	
	Σ215	56	20	7	4	2	2	3	1	1	3
Mar 1-Apr 15	881	71	21	4	2	1	1	t	t	t	
% > 20 tons = 9											
Apr 16 -May 30	499	59	20	8	4	2	2	2	1	1	2
% > 20 tons = 22											

Month.	C/f (NonP)	C/f (P)	Mean Depth of 23°I isotherm
Jan	2.48	5.70	170
Feb	2.66	3.67	200
Mar	8.16	6.26	145
April	11.76	9.54	115
May	12.03	5.55	105
June	6.38	7.86	130

$\rho[C/f\ (NonP), 23°D] = -0.94^{**}$, $\rho[C/f\ (P), 23°D] = -0.66$ ns

23°C — min acceptable temp for small yellowfin

Logged Set data for Study Area

Month	# sets Porpoise associated		# sets Non Porpoise	
January	46	[illegible]	4	[illegible]
February	185	[illegible]	50	[illegible]
March	461	[illegible]	1165	[illegible]
April	853	[illegible]	2219	[illegible]
May	195	[illegible]	604	[illegible]
Total logged	1940	[illegible]	4042	[illegible]
Total examined in Present study (all requisite data available)	556	[illegible]	1382	[illegible]
	(28.7%)	([illegible]%)	(29.2%)	([illegible])
		[illegible] SR		.62 SCR

Table 3

TABLE 1. Single set data for areas of overlapping effort between size class 3 and size class 6 vessels with 10 or more days effort applied by each.

1973

	Days	Catch per set							Total	Mean		Successful
	F	0	10	20	30	40	50	60	sets	catch		sets
PS-3	392	161	82	19	9	2	2		275	1,080		114
% total		58.5	29.8	6.9	3.3	0.7	0.7		catch/succ. set		=	9.47
% successful			71.9	16.7	7.9	1.8	1.8		succ. set ratio		=	0.415
% days F on porpoise = 26									sets/days F		=	0.702
									catch/days F		=	2.76
PS-6	983.5	330	380	186	106	55	38	19	883	17,185		553
% total		37.4	43	21	12	6.2	4.3	2.1	catch/succ. set		=	19.46
% successful			68.7	33.6	19.2	9.9	6.9	3.4	succ. set ratio		=	0.626
									sets/days F		=	0.898
% days F on porpoise = 86									catch/days F		=	10.94
									ratio of $\frac{PS\ 6}{PS\ 3}$ CPUE=			3.26
1974												
PS-6	1,075.5	281	433	172	87	36	28	7	1,066	12,125		785
% total		26	41	16	8	3	3	1	catch/succ. set		=	15.45
% successful			55	22	11	5	4	1	succ. set ratio		=	0.736
									sets/days F		=	0.991
									catch/days F		=	11.27
PS-3	346	123	109	38	20	15	7	5	323	3,200		200
% total		38	34	12	6	5	2	2	catch/succ. set		=	16.00
% successful			55	19	10	7.5	4	2.5	succ. set ratio		=	0.62
									sets/days F		=	0.934
									Catch/days F		=	9.26
									Ratio of $\frac{PS\ 6}{PS\ 3}$ CPUE=			1.22

TABLE 2

1973

LOGGED DATA

Porpoise	March 1-31	April 1-15	Σ	April 16-30	May 1-30	Σ	
0600-0859							
# sets	37	48	85	34	7	41	126
est.tons	615	1055	1670	490	85	575	2245
tons/set	14.19	21.98	19.65	14.41	12.14	14.02	17.81
0900-1159							
# sets	69	46	115	30	12	42	157
est.tons	1205	1290	2495	580	210	790	3285
tons/set	17.10	28.04	21.70	19.33	17.50	18.81	20.92
1200-1459							
# sets	47	34	81	28	6	34	123
est.tons	1050	755	1805	625	140	365	2570
tons/set	22.34	22.21	22.28	22.32	23.33	22.5	20.89
150-Sundown							
# sets	46	59	105	43	10	53	158
est.tons	870	1390	2260	625	155	780	2980
tons/set	17.61	23.56	21.52	14.53	15.50	14.72	18.86
Σ	199	187	386	135	35	170	556
	3680	4490	8170	2320	590	2910	10,361
	18.49	24.01	21.17	17.19	16.86	17.12	19.93
Schools							
0600-0859							
# sets	70	124	194	54	38	92	286
est.tons	950	1265	2215	200	560	1260	3475
tons/set	13.57	10.20	11.42	12.96	14.73	13.70	12.15
0900-1159							
# sets	108	134	242	77	64	141	383
est.tons	989	1130	2119	1430	830	2260	4379
tons/set	9.16	8.43	8.76	18.57	12.97	16.03	11.43
1200-459							
# sets	86	140	226	77	52	129	355
est. tons	790	1450	2240	1005	1195	2200	4440
tons/set	9.19	10.36	9.91	13.05	22.98	17.05	12.52
1500-Sundown							
# sets	87	134	221	76	61	137	358
est.tons	830	1465	2295	1005	920	1925	4220
tons/set	9.54	10.93	10.38	13.22	15.08	14.05	10.36
Σ	351	532	881	284	215	499	1382
	3559	5310	8869	4140	3505	7645	1654
	10.14	9.98	10.07	14.58	16.30	15.32	11.95