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STATISTICAL GUIDELINES FOR A PILOT OBSERVER PROGRAM TO ESTIMATE TURTLE TAKES IN THE HAWAII LONGLINE FISHERY

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Southwest Fisheries Science Center

NOAA Technical Memorandum NMFS

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Abstract

Statistical guidelines are described for the development of a pilot scientific observer sampling program to collect turtle interactions data from the Hawaii longline fishery. The best available data are presented and potential sources of variability in longline turtle take rates are discussed. A stratified sampling design for a pilot survey is developed based on time and target species. An array of sample size choices for the pilot program is presented covering a range of tolerance levels and confidence levels for estimation of total turtle take.

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INTRODUCTION

This report provides statistical guidelines for the development of a scientific observer sampling program to collect turtle interactions data from the Hawaii longline fishery. The development and implementation of the sampling program is a requirement of a recent internal Biological Opinion rendered under a Section 7 Consultation conducted by the National Marine Fisheries Service (NMFS) in response to concerns regarding the incidental taking of listed sea turtles by the Hawaii longline fishery. Data from the observer program will allow for the (1) characterization of turtle-longline interactions, (2) spatio-temporal analysis of interactions, (3) identification of "problem" areas and time periods, (4) calculation of estimates of turtle take rates and total take estimates, and (5) verification of submitted Hawaii longline logbooks.

The intent of the report is to provide *statistical guidelines* for the development of an observer sampling program based on the best available information. Although recommendations of survey design characteristics are proffered, decisions regarding sample size are deferred to the NMFS Southwest Region, Pacific Area Office (PAO). However, requisite data to facilitate sample size decisions are provided. It should be noted that this report does not address implementation of the sampling program, which is also deferred to the PAO.

The report specifically identifies and describes (1) background on the problem, (2) sources of data available to develop the sampling program, (3) a pilot survey design based on best available data, (4) efficient sample design characteristics (sampling frame, strata to sample), (5) pilot survey sample size requirements to obtain a desired precision, and (6) appropriate sample selection procedures.

BACKGROUND

In response to fishery interaction concerns resulting from the rapid growth of the Hawaii longline fishery in the late 1980s and the increased incidental take of protected species in the longline fishery, the Western Pacific Regional Fishery Management Council (WPRFMC) implemented a Federal fishing logbook system for domestic longliners operating in the western Pacific region. The primary objective of the logbook system, implemented in November, 1990, is to obtain statistically reliable information on (1) fishing effort and catch and (2) the take of protected species. Coincident with the adoption of the logbook system was the implementation of a Federal permit program for longline vessels. In addition, a voluntary observer sampling program was implemented in 1990 to document interactions between longline vessels and protected species and to collect ancillary detailed catch and effort data.

To participate in the Hawaii longline fishery, vessels must possess a current permit and submit logbooks of daily fishing activity. The Federally mandated longline fishing logbook system requires fishers to submit logbooks within 72 hours after a catch is off-loaded. Data provided by logbooks include gear configuration, fishing area, time, and catch for each longline set within a trip. When the logbook data are edited by NMFS, each logbook trip is assigned a target species trip type classification (broadbill swordfish, tuna or mixed-species target; see below) based on examination of the logbook data or interviews with the vessel captain or deck boss. When the captain is unavailable or the logbook is mailed in, trip type is determined by analyzing the times of the sets, the number of light sticks used, the area fished, type of gear fished, and previous information on trip type for that particular vessel. The assigned trip type designation applies to longline sets within a trip. A thorough description of the logbook system is found in Dollar and Yoshimoto (1991).

DATA SOURCES AND ESTIMATES OF TAKE RATE VARIABILITY

Data available to develop the sample survey design include 1991 and 1992 Hawaii longline logbook and 1990-92 observer data. A brief description and characterization of each data source follows.

Logbook Data

In 1991, out of a total of 153 vessels permitted to fish longline gear, 140 actively fished. In 1992, a total of 123 of 166 permitted vessels actively fished. The spatial extent of the longline fishing effort is depicted in Figure 1. The distribution of fishing trips by trip type (target species) and associated number of sets fished in the 1991 and 1992 fishing seasons are shown in Table 1. During 1991, 20% of the trips were designated as "swordfish", 33% as "tuna", and 47% as "mixed". During 1992, 25% of the trips were designated as swordfish, 36% as tuna, and 39% as mixed. While differences in trip type distributions were observed between years, the ranking order was unchanged. Monthly distributions of effort by trip type are presented in Figure 2 and reflect known tuna and swordfish availability patterns. The swordfish season generally runs from April to June while the tuna season runs from October to March.

Spatial delineations of fishing effort occur based on target species availability. Tuna fishing trips are generally proximal to the Hawaiian Islands with mixed trips north of the tuna effort and swordfish effort north of the mixed effort. This pattern of fishing effort is generally consistent for all months. Because target designations apply to all sets within a trip, the spatial pattern of effort in terms of sets is similar to the pattern for trips. The monthly spatial distributions of effort in terms of sets are depicted in Appendix A, by 1° latitude x 1° longitude statistical area.

Although varying targets from trip to trip is common, significant numbers of vessels exclusively target swordfish, tuna, or some mix of both. For example, during the 1991 fishing season 28% of the longline vessels fished exclusively for tuna, 11% fished exclusively for swordfish, and 24% always fished for a mixed catch. The remaining vessels (37%) switched between targets from trip to trip with no obvious pattern. During the 1992 fishing season 30% of the longline vessels fished exclusively for tuna, 19% fished exclusively for swordfish, 31% always fished for a mixed catch, and 20% switched between targets. The identification of exclusive groups of vessels within the longline fishery is basic to developing strata and sampling frames.

Estimates of mean turtle take rates and associated standard deviations based on logbook data are listed in Table 2. Because the logbook data theoretically represent all fishing activity and turtle takes occurring during a year (i.e., a census), they provide an overall mean take rate estimate with zero standard error. However, standard deviations of the logbook take rates are given in Table 2 for purposes of comparison with observer data (see below). Estimates of mean turtle take rates and associated standard deviations by trip type for logbook data are listed in Table 3. Higher mean turtle take rates were associated with trips targeting swordfish, followed by trips targeting a mixed catch and tuna. The percent frequency distribution of turtle takes per set is listed in Table 4. While no turtle interactions were reported for the majority of sets (99%).

Observer Data

A total of 11 trips (109 sets) were monitored by scientific observers in the longline fishery between 1990 and 1992. Because a full-fledged observer program had not been established at the time, cooperating vessels were sampled opportunistically. All vessels monitored fished exclusively for swordfish. The spatial distribution of the observer effort and turtle takes are shown in Figure 3. A total of 7 turtle interactions were observed on 3 of the 11 monitored trips. The percent frequency distribution of turtle takes per set is listed in Table 4. No turtle interactions were recorded for the majority of observed sets (95%).

The average take rate in observed sets and the associated standard error are shown in Table 2. Assuming that the 109 observed sets were representative of all sets in 1992, the total turtle take for 1992 also was estimated (Table 2). This estimate was computed using a ratio estimator (Cochran 1977):

$$\textit{Total take} = \frac{\sum_i \sum_j x_{i,j}}{\sum_j n_j} \cdot N, \tag{1}$$

where $x_{i,j}$ is observed turtle take in set i of trip j; n_j is the number of sets fished in trip j; N is total fleet effort expressed as number of sets and is derived from logbook data. The standard error of the total take estimate and a confidence interval for total turtle take were estimated by bootstrap resampling (Efron 1982). An empirical frequency distribution of total take estimates was generated, then approximate upper and lower 90% confidence limits for total take were computed as the 5^{th} and 95^{th} percentiles of the bootstrap distribution.

A comparison of turtle take rate estimates between data sources shows that the observer turtle take rate is considerably higher than that reported by fishers in the logbooks (Table 2). Accordingly, the estimated total take of turtles based on observer data is also considerably higher than that reported in the logbooks. These findings are consistent with the recent Biological Opinion (however, the data used in this paper are more complete and current). Variability associated with the estimated total take of turtles in 1992 is high, reflecting both between-set variation in the turtle take rate and the small observer sample size.

Because logbooks report the daily catch of fish, fishing effort, and take of protected species by participating vessels ideally they provide a census of fishing activities. However, the accuracy of data collected by the logbook system depends in part on the amount of under-reporting and non-reporting of fishing effort, catch and take of protected species. While no rigorous verification analysis of the Hawaii longline logbook system has been conducted, the logbook data are considered to be suspect in several respects. The reported bycatch of certain fish species, in particular sharks, is likely under-reported. The reported take of protected species is likely downwardly biased due to non-reporting. The non-reporting of turtle takes by fishers in the longline logbook system is believed to be responsible for differences between logbook-derived and provisional observer-derived turtle take rates (Table 2). However, as the available observer data set is small (11 trips) and limited to vessels fishing exclusively for swordfish, the data are not considered to be representative of turtle interactions in the Hawaii longline fishery and too meager to assess accuracy and bias of the total take estimate.

Moreover, while the logbook data suggest the need for stratification by trip-type, the development of an efficient stratified survey program will require additional reliable baseline turtle interactions data. To collect such data a pilot observer stratified sampling survey is proposed. Stratification is one of the most widely used techniques in sample survey design serving the dual purposes of providing samples that are representative of all major subgroups of the population and of improving the precision of estimators (Cochran 1977). Stratified sampling exploits a population's heterogeneity, resulting in more precise estimates compared to simple random sampling.

PILOT SAMPLE SURVEY DESIGN

The objective of the pilot stratified sample survey is two-fold. Data from the pilot survey will allow for 1) the characterization of turtle interactions in the longline fishery and 2) the estimation of the total turtle take (all species combined). While the pilot survey design is not intended to be optimal for long-term routine monitoring it represents our best approach until additional data become available. These data will allow NMFS to optimize future sampling and if necessary design more complex multiobjective sampling programs. For example, surveys could be designed to provide specified statistical accuracy with respect to the take of an individual turtle species (e.g., an endangered species), rather than just the total take of all turtle species; more ambitious surveys would require more observer trips and incur higher cost. In addition, future designs will consider alternative ways of combining logbook and observer data to estimate the total turtle take, and ways to achieve the same statistical objectives at lower overall cost.

The statistical design for a pilot observer program described below provides for unbiased estimates of the turtle take. Data from the logbooks were used to identify appropriate strata and sampling frames while observer data were used to estimate sample size requirements.

Sources of Variability

Development of an efficient stratified sample survey relies in part on the identification of sources of variability affecting turtle take rates and their incorporation into the sampling design. Factors related to the variability of turtle take rates constitute stratification variables. The precision of estimators increases as more of the sources of variability (stratification variables) are accounted for within the sampling survey. However, sources of variability in turtle take rates are poorly known; hence the need for a pilot survey. As many factors affecting the catch of target species likely affect turtle take rates, initial stratification will be based on characteristics of the fishery. While the optimal approach would be based on proven sources of variability, the use of fishery characteristics as provisional stratification variables does allow for the characterization of turtle interactions in the longline fishery, one of the survey objectives.

Because longline vessels actively target specific species (or groups of species) and each target requires a different catch strategy, the longline fleet can be viewed as consisting of target species subgroups. These subgroups operate seasonally with effort linked to target species availability. While local availability of target species likely depends on environmental factors, characteristics of the vessel (e.g., length) and deployed gear (e.g., number of light sticks) also affect catch. Many of these factors likely affect turtle take rates as well. Despite the array of potential factors affecting catch, most of the observed variability in catch rates can be explained by time or target species. For example, the spatial distribution of vessels is linked to target species availability. Generally speaking, tuna vessels consistently fish in the vicinity of the main Hawaiian Islands, vessels with a mixed target fish north of tuna vessels and swordfish vessels fish north of mixed vessels (see Appendix A). Therefore, spatial variability in turtle take rates can be accounted for by vessel type (tuna, swordfish, or mixed).

Vessel lengths range from approximately 30 to 95 feet in the longline fishery: the smallest vessels targeting tuna, the largest targeting swordfish, and medium-sized vessels targeting a mixture of species. A similar pattern was observed for vessel horsepower. While these factors affect fishing power, and ultimately catch, vessel length is related to vessel trip type.

Differences in gear configuration and fishing strategy (number of hooks and light sticks) are related to target species. The number of hooks per set is highest when a vessel is targeting tuna, followed by mixed and swordfish (Table 5). The number of light sticks per set is highest when targeting swordfish, followed by mixed and tuna (Table 5). Differences in set duration and total number of sets per trip are also related to target (Table 6). The fact that a unique gear configuration and fishing strategy are associated with the mixed trip type reflects the fact that these fishers are actually targeting a mixed catch.

Thus, two stratification variables are proposed for the pilot survey: time (see below), and vessel trip type. In the survey design, all potential vessel trips are classified into a unique stratum defined by time and trip type. To facilitate sampling, vessel trips within trip type*time strata are defined as the primary sampling units (PSU). A list of primary sampling units belonging to each stratum represents the sampling frame and provides the basis for the selection and identification of the units in the sample. Longline sets within a given vessel trip are defined as the secondary sampling units from which turtle take data will be collected. Design elements of the stratified sample survey are discussed below.

Sample Size Requirements and Allocation

Sample size determination is oriented towards controlling the variance of an estimator. Given prior estimates of variability, sample size as a function of acceptable or tolerable error and confidence level can be determined. By determining the sample size for various combinations of tolerable error and confidence level trade-offs between sample size and desired properties of the estimator can be evaluated.

While it is not the intent of this report to recommend a sample size for the pilot survey, data to facilitate sample size determinations are given. Sample size requirements (in terms of the number of sets) for estimating total turtle take, as a function of acceptable or tolerable estimation error and confidence level, were calculated using observer data. The observer dataset is the most reliable source of information available from which estimates of mean take rate and variance of take rate can be calculated. To provide a wide range of options, sample size requirements were computed at several levels of tolerable error (5% to 70%) and confidence level (99% to 60%).

Sample sizes were determined under two scenarios. Scenario one assumes a normal take rate distribution; scenario two assumes that the distribution of turtle takes (counts) conforms to the negative binomial. Calculations based on the negative binomial distribution treat the catch of turtles as a rare, contagious event.

Assume we have a population (sampling frame) of N sets. Denote the turtle take in a single set by X. Let μ denote the mean turtle take per set and σ^2 the between-set variance in turtle take. The coefficient of variation of the catch per set is $CV(X) = \sigma/\mu$. Our objective is to estimate the total turtle take, T, defined as $T = N*\mu$. Logbook data should provide the value of N so we consider it known. The mean and variance of X are unknown but can be estimated from a random sample of n sets drawn from the population. Given a sample of n observed sets, denote the moment estimators of μ and σ^2 by $\bar{X}$ and S^2, respectively.

The total turtle take is estimated by $T^* = N*\bar{X}$ with variance $V(T^*) = N^2*\sigma^2/n$. The latter is estimated by the sample statistic N^2*S^2/n. The coefficient of variation of the total take estimate is $CV(T^*) = \sigma/(\mu\sqrt{n}) = CV(X)/\sqrt{n}$. Thus we derive the following relationship:

$$n = [CV(X) \;/\; CV(T^*)]^2, \qquad (2)$$

which can be used to compute the sample size required to estimate T with a specified target coefficient of variation, given an estimate of relative variation in the take rate, CV(X). This result may be sufficient for some purposes but does not address the likelihood that the desired level of accuracy in T^* will be achieved. Accordingly, we consider the following probability statement of our sampling objective:

$$Prob[|T^* - T| \leq \delta T] = 1-\alpha, \tag{3}$$

which states that we wish to estimate the total take within 100δ% of its true value with 100(1-α)% confidence. The symbol δ is the tolerable error, expressed as a decimal fraction. Within the brackets divide both sides of the inequality by the standard error of the total take estimate, $N\sigma/\sqrt{n}$. Upon substituting appropriate sample statistics we have the equivalent probability statement:

$$Prob\{\frac{\sqrt{n}|\overline{X} - \mu|}{S} \leq \frac{(\delta\sqrt{n})}{CV(X)}\} = 1-\alpha. \tag{4}$$

The quantity on the left-hand side of this inequality has a Student's t distribution with n-1 degrees of freedom. Thus, for a specified value of α we simply need to solve:

$$t_{\alpha,n-1} \leq \frac{(\delta\sqrt{n})}{CV(X)}. \tag{5}$$

The solution is

$$n \geq \{t_{\alpha,\infty}CV(X)/\delta\}^2. \tag{6}$$

Equation (6) was used to compute sample size requirements as a function of tolerable error and confidence level, assuming a normal take rate distribution. For a given confidence level, the data were plotted showing the relationship between n and δ (Figure 4). It is assumed above that no finite population correction factors are needed.

Assuming a negative binomial take rate distribution, sample size requirements are given by (Elliott 1971):

$$n = \frac{(t_{\alpha,\infty})^2}{\delta^2}\left(\frac{1}{\bar{X}} + \frac{1}{k}\right), \quad (7)$$

where n is sample size; $\bar{X}$ is the sample mean; k = $(\bar{X}^2-(S^2/n))/S^2-\bar{X}$ (an approximation); S^2 is the sample variance. Sample size requirements for a given confidence level are plotted in Figure 5.

From these plots one can see the trade-offs between sample size, tolerable error and confidence level. Within each scenario, sample size requirements are positively related to confidence level while between scenarios sample size requirements are consistently higher under the negative binomial assumption.

While sample size requirements were determined at the set level, the primary sampling unit in the proposed sample survey is a vessel trip. For practical purposes the required number of sets to sample, n, from either equation 6 or 7, must be converted to number of trips, m. The number of trips is then allocated among strata. Approximately 10 sets comprise a trip (Table 6); thus a factor of 1/10 was used to convert required number of sets to required number of trips.

To allocate total sample size in the pilot observer program among strata, a two-step proportional allocation scheme is suggested. The first step allocates total sampling effort based on the temporal distribution of fishing effort. The second step allocates available sampling effort between trip type strata based on the temporal distribution of trip types. The following equation can be used to allocate sampling effort:

$$m_{i,j} = W_{i,j} \cdot m, \quad (8)$$

where $m_{i,j}$ is sample size (number of trips) in time stratum i that are of trip type j; $W_{i,j} = a_{i,j} * b_i$ and is a sample allocation weighting factor; m = n/10 and is total sample size expressed as vessel trips where n is from equation (6) or (7); $a_{i,j}$ is the proportion of trips in time stratum i that are of trip type j; b_i is the proportion of the total sets executed in time stratum i. Estimates of the weighting factor $W_{i,j}$ can be calculated from logbook data. Once the total sample size (m) has been chosen, the allocation of sampling effort among strata is a relatively simple exercise.

The proposed pilot sampling survey is based on a simple proportional allocation scheme, and is not necessarily the most efficient design for long-term routine monitoring. Proportional allocation distributes sampling effort based on stratum sizes and assumes equal costs per observation in all strata as well as equal variances in all strata. While these assumptions are likely violated, proportional allocation is generally used when stratum variances cannot be approximated before sampling. Using cost per sample and stratum variances to allocate sampling effort (Neyman allocation) generally results in more efficient allocation of sampling effort (Cochran 1977). Data from the pilot sampling program will allow us to use Neyman allocation in future survey designs.

Sampling Strata and Sampling Frame

The identification of exclusive vessel groups (tuna, swordfish, and mixed) within the longline fleet simplifies development of trip type*time strata. Implementation of the pilot sampling program will require knowing, in advance, which trips from a particular vessel will be targeting swordfish, tuna, or a mixed catch (i.e., the vessel's trip type) during a specified time period prior to the selection of sampling units. This implies that real-time information about the status of all vessels (i.e., in port, at sea, expected departure dates, expected arrival dates, etc.) is available.

The classification of fishing vessels in the 1991 and 1992 fishing seasons by trip type is outlined in Table 7 and was accomplished using a vessel classification decision rule. Vessels which targeted tuna on 80% or more of their trips comprise the tuna trip type stratum, vessels which targeted swordfish on 80% or more of their trips comprise the swordfish trip type stratum, vessels which targeted a mixed catch on 80% or more of their trips comprise the mixed trip type stratum, and vessels switching between targets (all other vessels) comprise the switcher trip type stratum. Some fishers included in the switcher stratum commit to a target only after leaving the dock. Treating switchers as a separate stratum will simplify logistics and should not affect the efficiency of the estimators.

While exclusive vessel groups are identifiable they are dynamic. As vessels drop out of the Hawaii longline fishery or change strategies the sampling frame will have to be adjusted. Prior to implementation of the pilot sampling program the fleet composition will need to be re-evaluated based on the most recent logbook data.

The identification of an efficient temporal stratification scheme relies in part on the temporal variation of the variable of interest, in this case turtle takes, and practical limitations associated with our choice of PSU (primary sampling unit), a vessel trip. In addition, stratum sample sizes must be sufficient to allow for the calculation of descriptive statistics. The paucity of reported turtle interactions made the identification of temporal strata, particularly at the level of trip type, impossible. Therefore, selection of the best temporal stratification was based on finding a practical or workable scheme that still allows sufficient temporal structure.

Practical limitations of the PSUs which impact the identification of temporal strata include maximum trip duration and an imposed minimum stratum sample size constraint. Maximum trip duration is a constraint determining the minimum size of the temporal stratum. Minimum stratum sample size is a statistical constraint and is set at three vessel trips to ensure the estimation of stratum take rate means and variances.

Kawamoto et al. (1989) reported average tuna trip durations of approximately 2 weeks. Swordfish trip durations of 23 days have been observed (Dollar 1991) but most swordfish trips are believed to range from 4 to 6 weeks (Dollar pers. commun.). While these results identify 4 weeks as the minimum size of a temporal stratum, the sample size constraint of 3 vessel trips still needs to be considered.

A numerical analysis was conducted to determine the best temporal stratification scheme. Monthly stratum sample size allocations under various assumed total sample sizes (*n* from equation (6)) were computed using equation (8) and compared with the PSU constraints. Tested temporal stratum sizes included 1-month, 2-months and 3-months (quarter). Tested total sample sizes included 50, 100, 200, 300, 400, and 500 vessel trips, believed to encompass the range of feasible *m* from which the PAO can choose.

For total sample sizes of 100 vessel trips or more the results identify <u>quarter</u> as the best temporal stratification scheme for all fleet segments of the Hawaii longline fishery (Tables 8 through 13). When total sample size equaled 50 trips the minimum stratum sample size constraint was violated in the swordfish trip type stratum. Although minimum total sample size was not being tested here, the results do provide a measure of the minimum total sample size required (i.e., 100 trips). Quarterly sample allocation weighting factors used in the analysis are given in Table 14.

In addition to meeting all PSU constraints, quarterly sampling strata for the Hawaii longline fishery are consistent with fishing seasons. Quarter 4 (October-December) spans the first half of the tuna season, and Quarter 1 (January-March) the last half. Quarter 2 (April-June) spans the swordfish season, and Quarter 3 (July-September) a mixed catch season.

Real-time information concerning the status of Hawaii longline vessels is currently being collected by the Fisheries Monitoring and Economics Program (FMEP) at the Honolulu Laboratory, NMFS. Among the information collected are daily recordings of which vessels are in port and at which pier each vessel was seen. Because these data are collected daily they provide a real-time inventory of vessels in port. Active vessels not observed in port are assumed to be at sea. While information collected by the FMEP can be used to identify possible sampling platforms within a quarter it provides no information concerning departure dates. To facilitate the pilot sampling program, procedures to collect departure date information or estimate departure dates from the port inventory data need to be developed and implemented.

Sample Selection

It is essential that a random selection procedure be used to select vessel trips within a particular trip type*time stratum. Vessel trips should be selected from the sampling frames using a random number table. In the event that a selected vessel trip is not available, another vessel trip should be selected using the random number table (with replacement).

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Table 1. Annual number of trips by trip type and associated number of sets fished (in parentheses) from logbook data.

Year	Trip Type			
	Swordfish	Tuna	Mixed	Total
1991	291 (3126)	550 (4318)	824 (5205)	1665 (12649)
1992	288 (3531)	468 (3868)	547 (4121)	1303 (11520)

Table 2. Annual estimates of mean turtle take rate (turtle take per set), take rate standard deviation, take rate standard error and total turtle take based on logbook and observer data. The numbers in parentheses are the upper and lower 90% confidence limits.

Data Source	Year	Reported Turtle Take	Mean Turtle Take Rate	Take Rate Standard Deviation	Take Rate Standard Error	Esti-mated Total Turtle Take
Logbook	1991	73	0.0058	0.0865	---	73
	1992	65	0.0056	0.0837	---	65
Observer	1992	7	0.0642	0.3126	0.0297	739 (89-1397)

Table 3. Annual logbook estimates of mean turtle take rate (turtle take per set) and take rate standard deviation by trip type designations.

Year	Trip Type	# Turtles Taken	# Sets Fished	Mean Turtle Take Rate	Take Rate Std. Dev.
1991	Swordfish	54	3126	0.0173	0.1269
	Mixed	14	5205	0.0027	0.0749
	Tuna	5	4318	0.0012	0.0342
1992	Swordfish	54	3531	0.0153	0.1380
	Mixed	9	4121	0.0022	0.0516
	Tuna	2	3868	0.0005	0.0227

Table 4. Number of turtles takes per set and associated percent frequency from logbook and observer data. The number in parentheses represents number of sets.

NUMBER TURTLES/SET	LOGBOOK 1991	LOGBOOK 1992	OBSERVER
0	99.49 (12584)	99.47 (11462)	95.41 (104)
1	0.47 (59)	0.45 (52)	2.75 (3)
2	0.04 (5)	0.04 (5)	1.84 (2)
3	0	> 0.01 (1)	0
4	> 0.01 (1)	0	0

Table 5. Reported number of hooks and light sticks deployed by trip type in the Hawaii longline fishery. The numbers represent the 25% and 75% quartiles.

Gear Configuration	Trip Type		
	Swordfish	Tuna	Mixed
Number of Hooks	650-800	1000-1560	900-1020
Number of Light Sticks	400-850	0	120-360

Table 6. Reported set duration (hours) and number of sets per trip by trip type in the Hawaii longline fishery. The numbers represent the 25% and 75% quartiles.

Fishing Strategy	Trip Type		
	Swordfish	Tuna	Mixed
Set Duration	12-14	8-10	11-12
Number of Sets	9-12	7-9	5-7

Table 7. Stratification of longline vessels by fishing strategy (number of vessels).

Year	Exclusive Targets			Switchers	Total
	Swordfish	Tuna	Mixed		
1991	17	37	37	49	140
1992	23	38	38	24	123

Table 8. Quarterly sample size (trips) allocations by fleet based on a total sample size (m) of 50. Quarterly sample sizes are the sum of fleet specific allocations and those in the switcher stratum that would likely be associated with each fleet.

Quarter	Fleet Allocated Sampling Effort (m)			Total
	Swordfish	Tuna	Mixed	
1	3	7	6	16
2	3	6	4	13
3	2	4	3	9
4	1	6	5	12
Total	9	23	18	50

Table 9. Quarterly sample size (trips) allocations by fleet based on a total sample size (m) of 100. Quarterly sample sizes are the sum of fleet specific allocations and those in the switcher stratum that would likely be associated with each fleet.

Quarter	Fleet Allocated Sampling Effort (m)			Total
	Swordfish	Tuna	Mixed	
1	7	11	14	32
2	7	8	14	29
3	4	5	9	18
4	3	10	8	21
Total	21	34	45	100

Table 10. Quarterly sample size (trips) allocations by fleet based on a total sample size (m) of 200. Quarterly sample sizes are the sum of fleet specific allocations and those in the switcher stratum that would likely be associated with each fleet.

Quarter	Fleet Allocated Sampling Effort (m)			Total
	Swordfish	Tuna	Mixed	
1	14	23	27	64
2	14	15	28	57
3	6	9	17	32
4	5	23	19	47
Total	39	70	91	200

Table 11. Quarterly sample size (trips) allocations by fleet based on a total sample size (m) of 300. Quarterly sample sizes are the sum of fleet specific allocations and those in the switcher stratum that would likely be associated with each fleet.

Quarter	Fleet Allocated Sampling Effort (m)			Total
	Swordfish	Tuna	Mixed	
1	20	34	41	95
2	20	23	42	85
3	12	14	25	51
4	8	32	29	69
Total	60	103	137	300

Table 12. Quarterly sample size (trips) allocations by fleet based on a total sample size (m) of 400. Quarterly sample sizes are the sum of fleet specific allocations and those in the switcher stratum that would likely be associated with each fleet.

Quarter	Fleet Allocated Sampling Effort (m)			Total
	Swordfish	Tuna	Mixed	
1	26	46	55	127
2	27	30	56	113
3	14	19	32	65
4	13	44	38	95
Total	80	139	181	400

Table 13. Quarterly sample size (trips) allocations by fleet based on a total sample size (m) of 500. Quarterly sample sizes are the sum of fleet specific allocations and those in the switcher stratum that would likely be associated with each fleet.

Quarter	Fleet Allocated Sampling Effort (m)			Total
	Swordfish	Tuna	Mixed	
1	34	57	69	160
2	32	38	70	140
3	18	24	43	85
4	14	54	47	115
Total	98	173	229	500

Table 14. Quarterly sample allocation weighting factors by fleet type.

Quarter	Fleet			
	Swordfish	Tuna	Mixed	Switchers
1	0.0261	0.0736	0.0572	0.1635
2	0.0271	0.0542	0.0588	0.1428
3	0.0194	0.0294	0.0284	0.0869
4	0.0181	0.0715	0.0378	0.1053

Hawaii Longline 1991-92

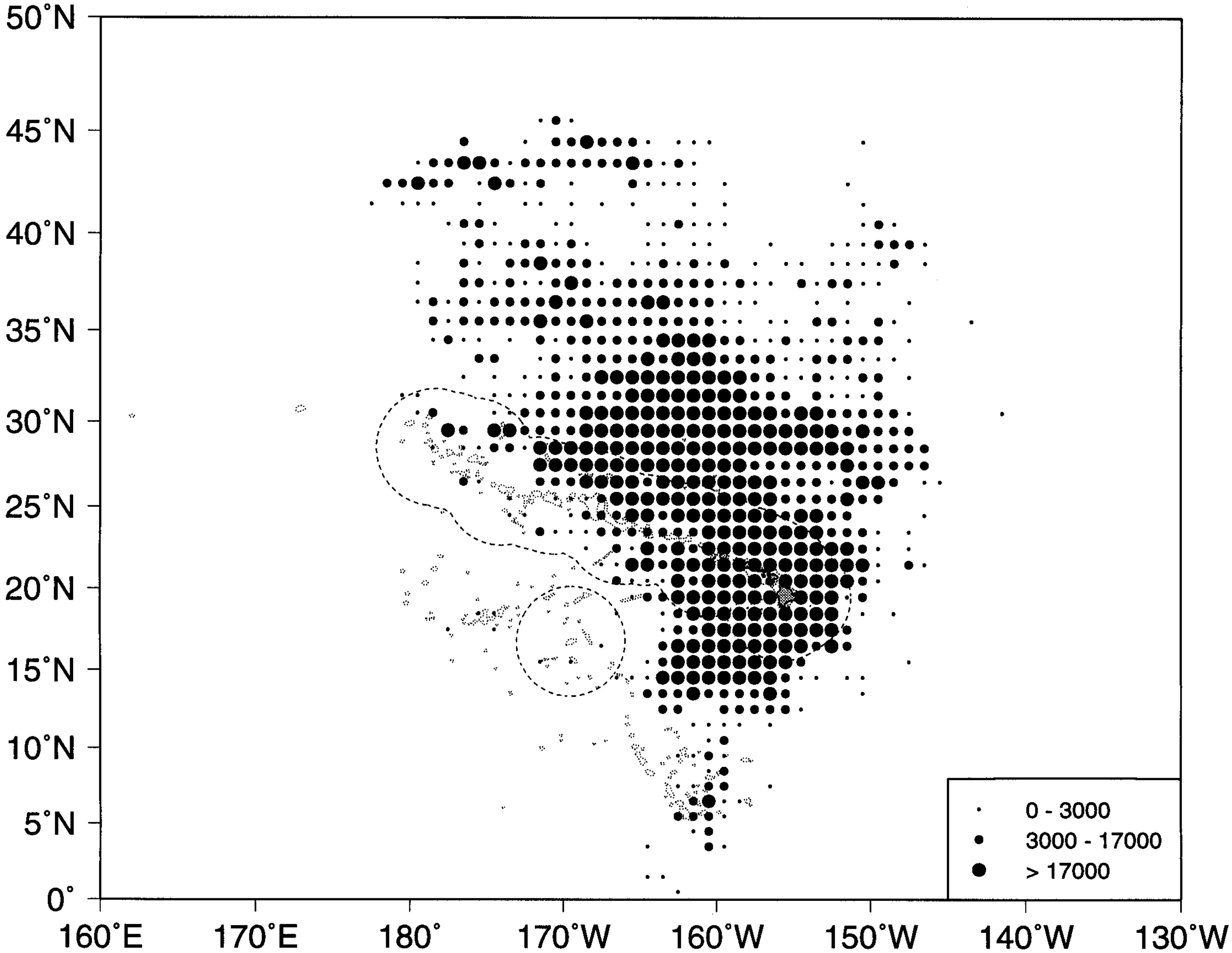


Figure 1. Distribution of reported fishing effort (number of hooks) in the Hawaii longline fishery, 1991 and 1992 combined.

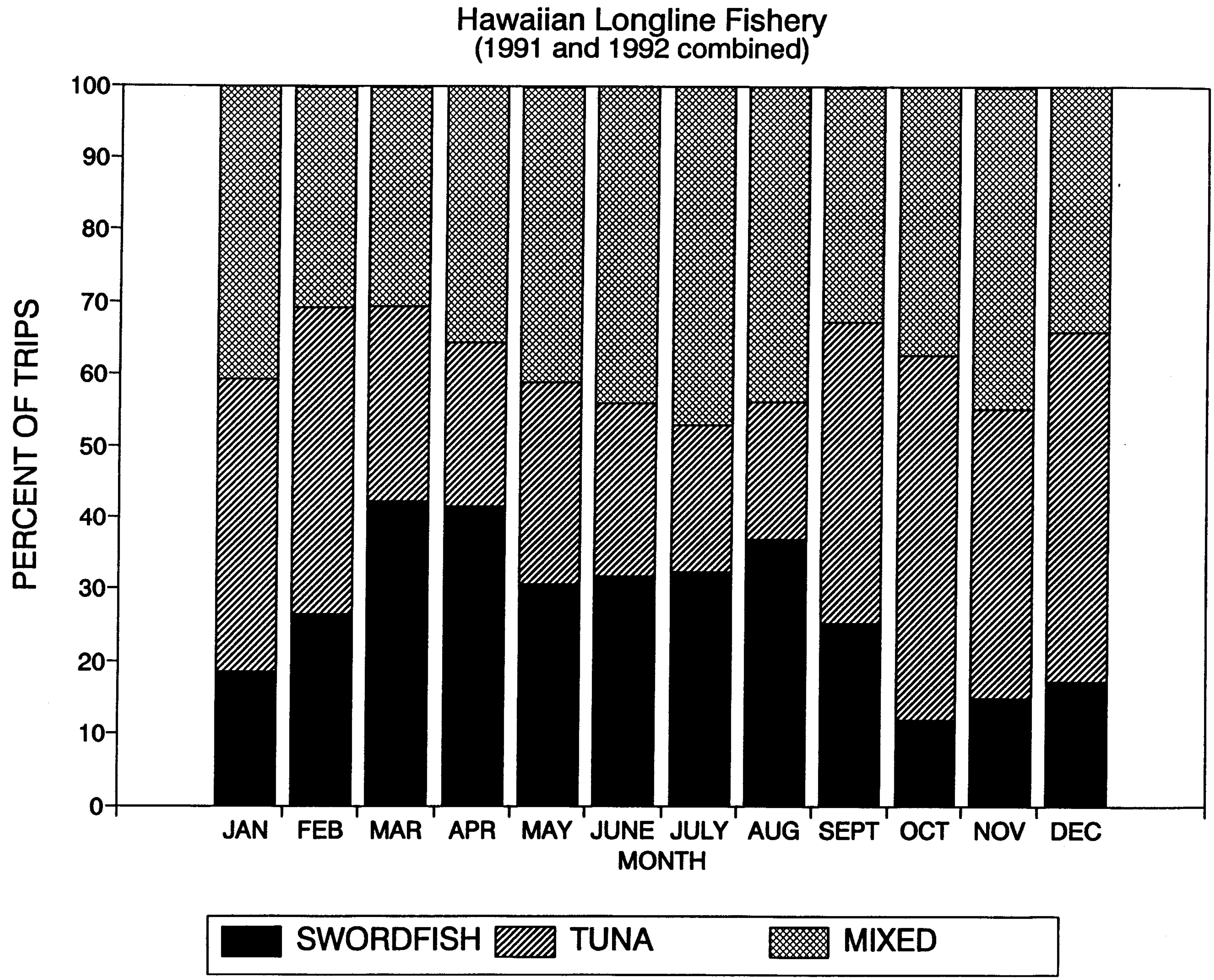


Figure 2. Monthly distribution of trip type in the Hawaii longline fishery.

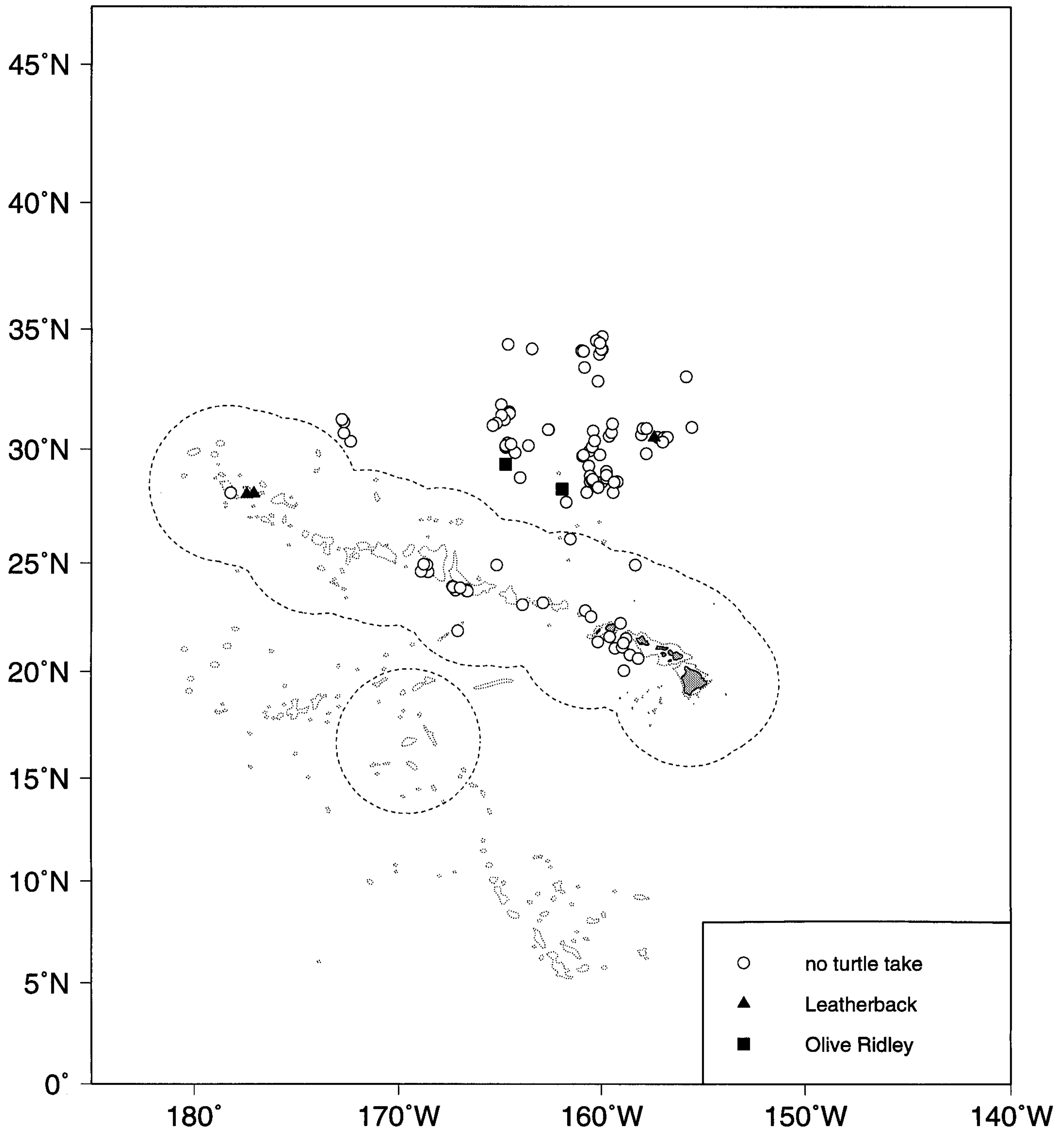


Figure 3. Distribution of observer sampling effort and turtle takes.

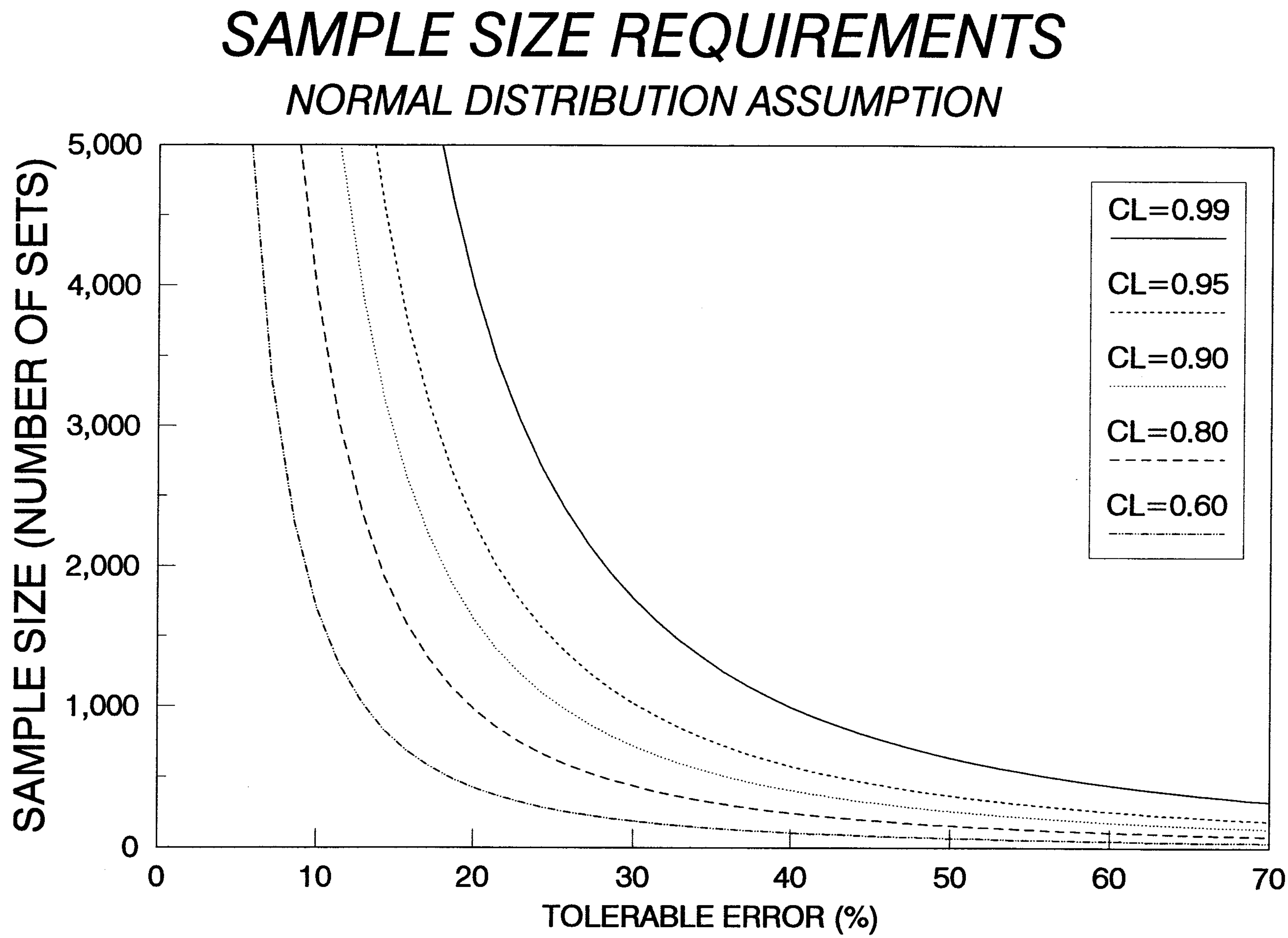


Figure 4. Sample size requirements as a function of percent tolerable error of total turtle take and confidence level (CL) assuming that the catch rate is distributed normally.

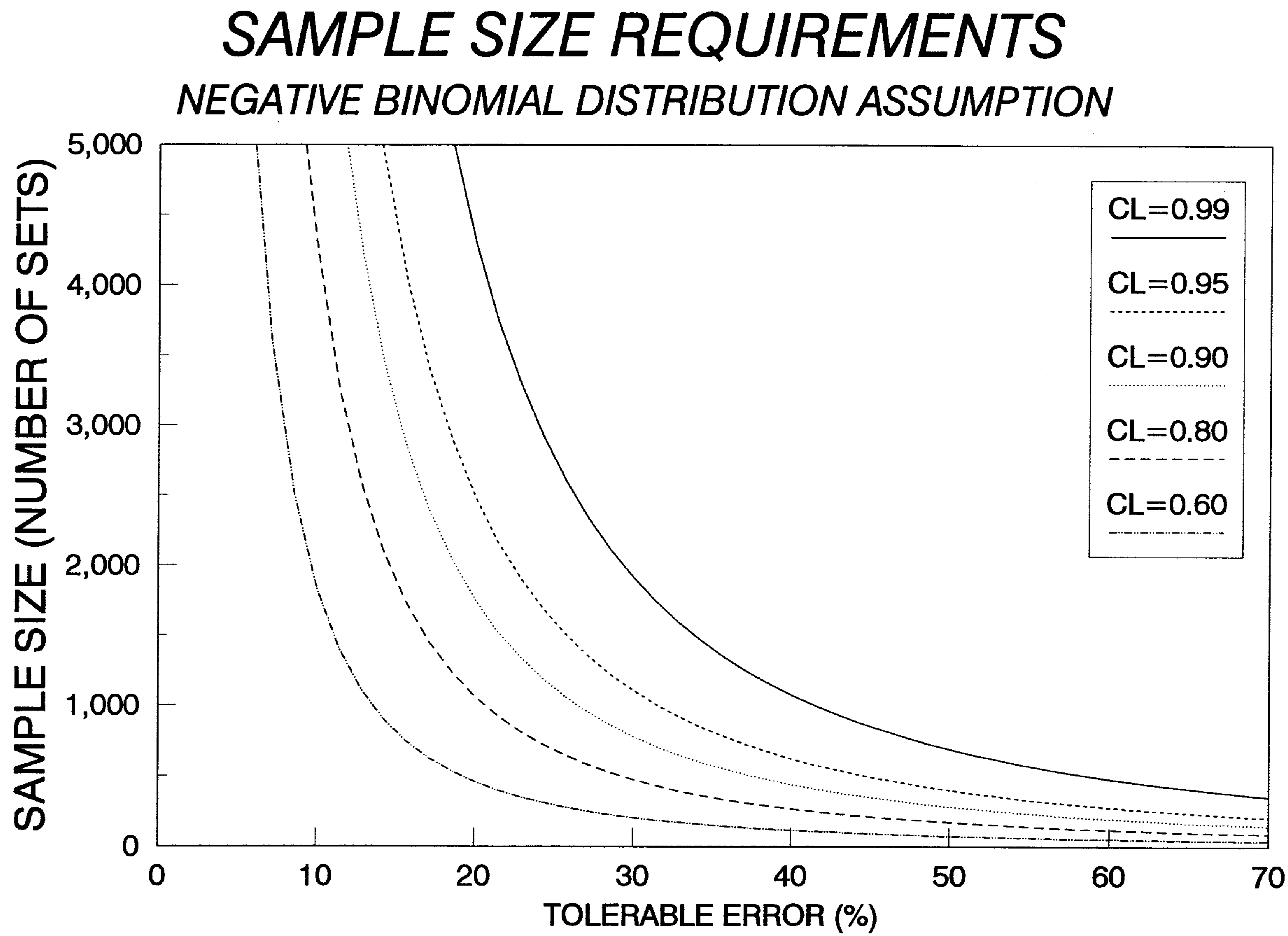
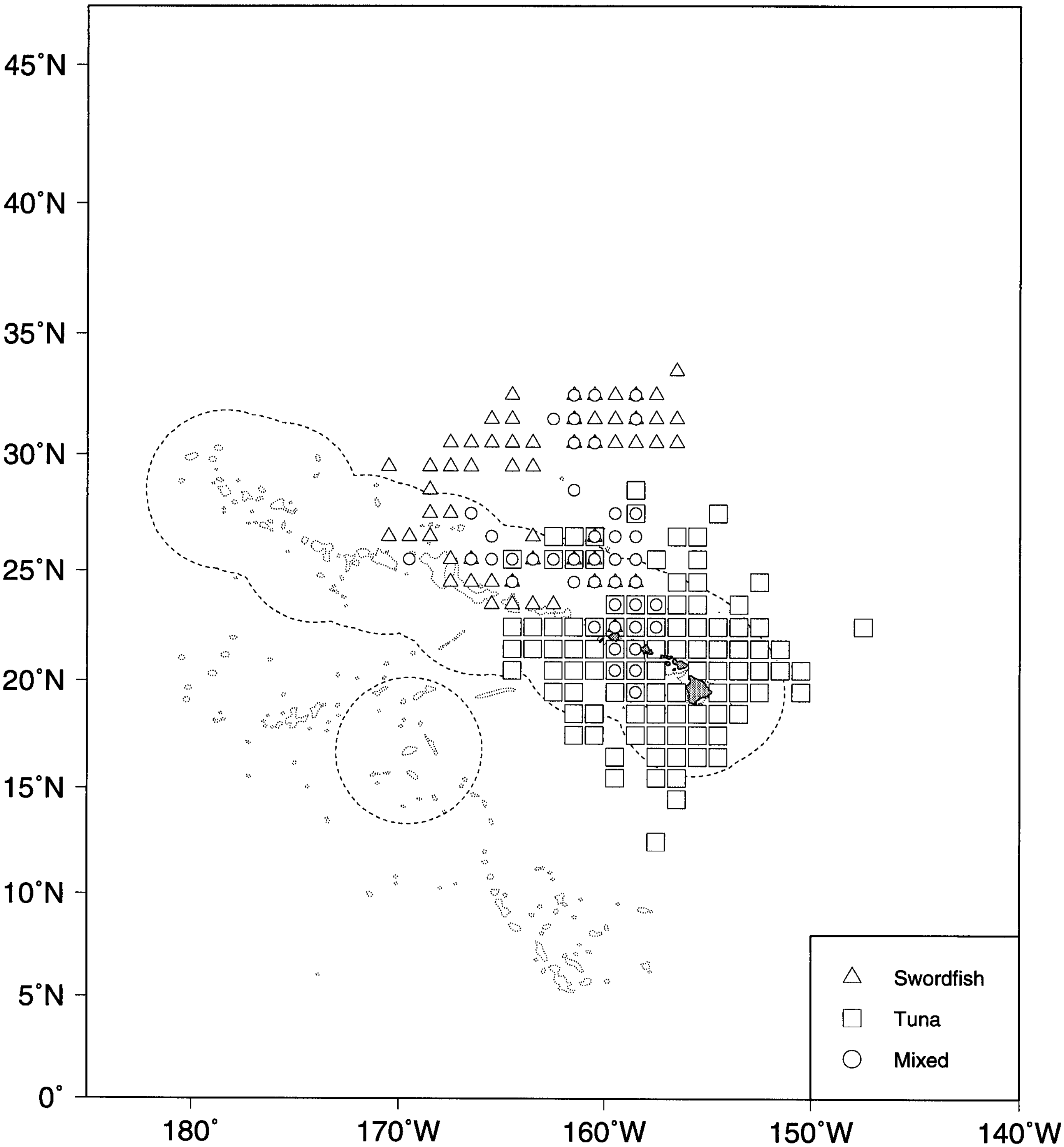


Figure 5. Sample size requirements as a function of percent tolerable error and confidence level (CL) assuming that the distribution of turtle takes conforms to the negative binomial.

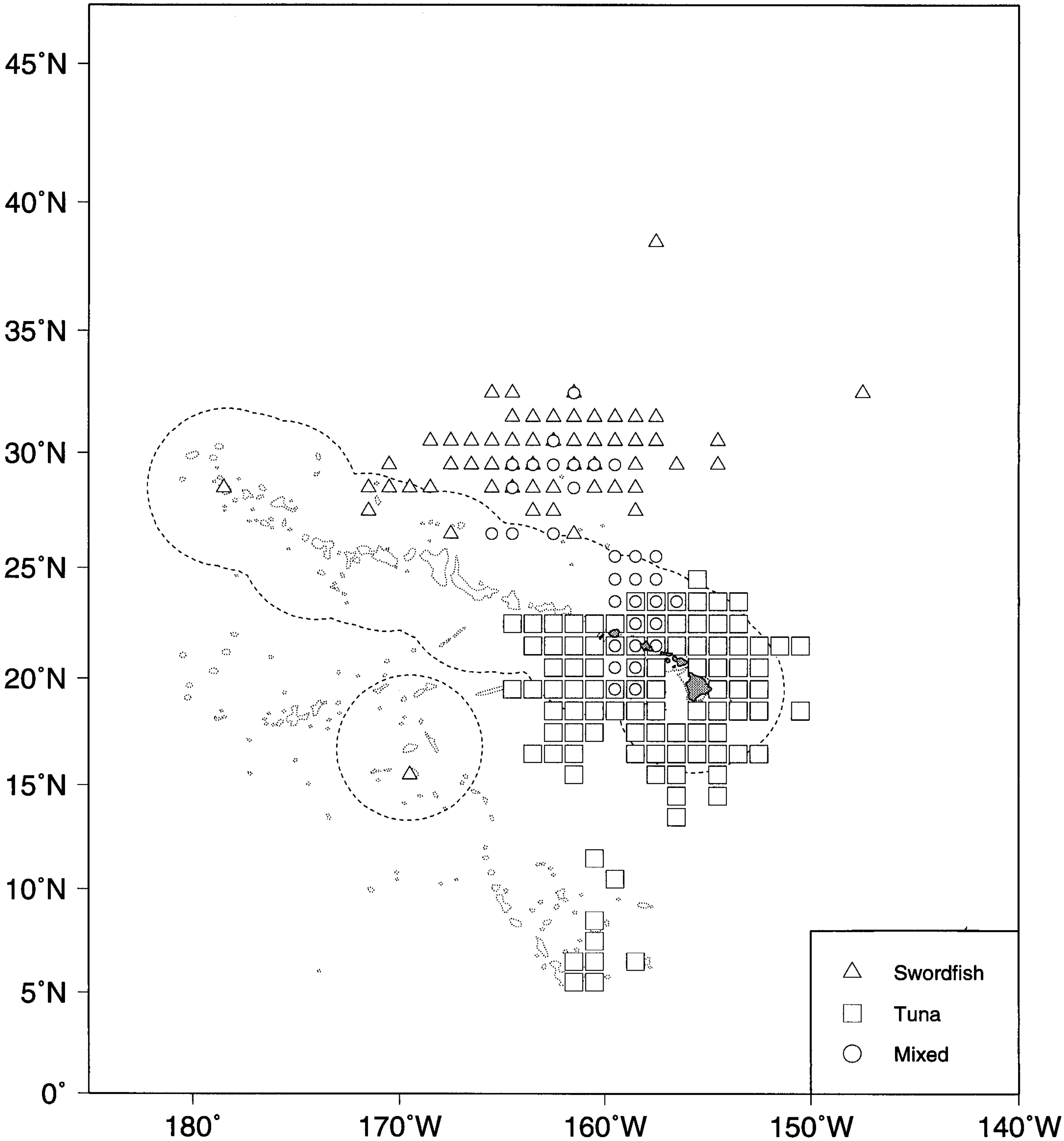
Appendix A. Location of fishing effort by set type (swordfish, tuna or mixed) in the Hawaii longline fishery, 1991 and 1992 combined. The dashed contours delineate the Exclusive Economic Zones (EEZ) for the Hawaiian Islands and Johnston Atoll. The dotted contours delineate the 200 fathom isobath.

Hawaii Longline Fishery - January



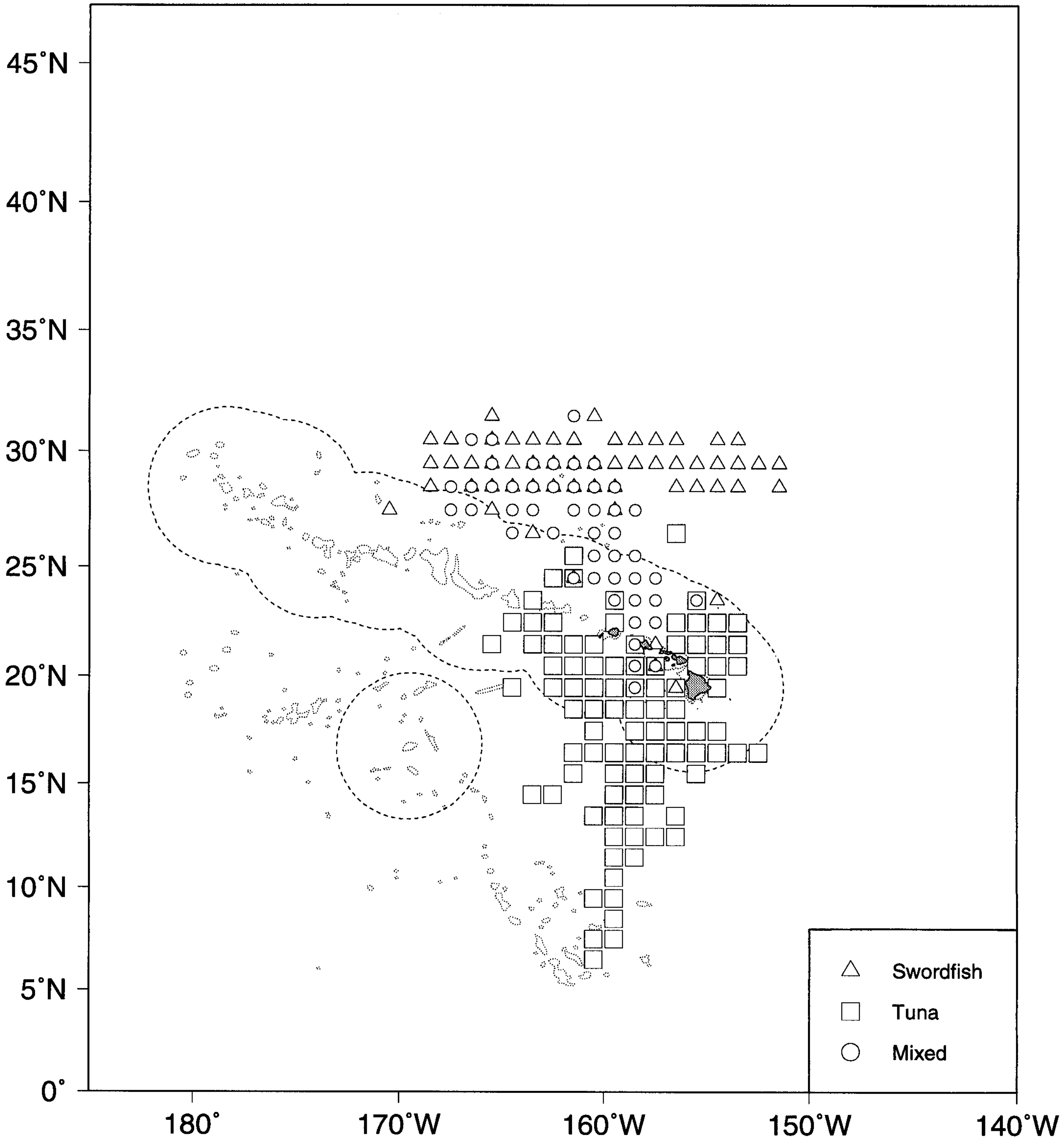
Appendix Figure 1

Hawaii Longline Fishery - February



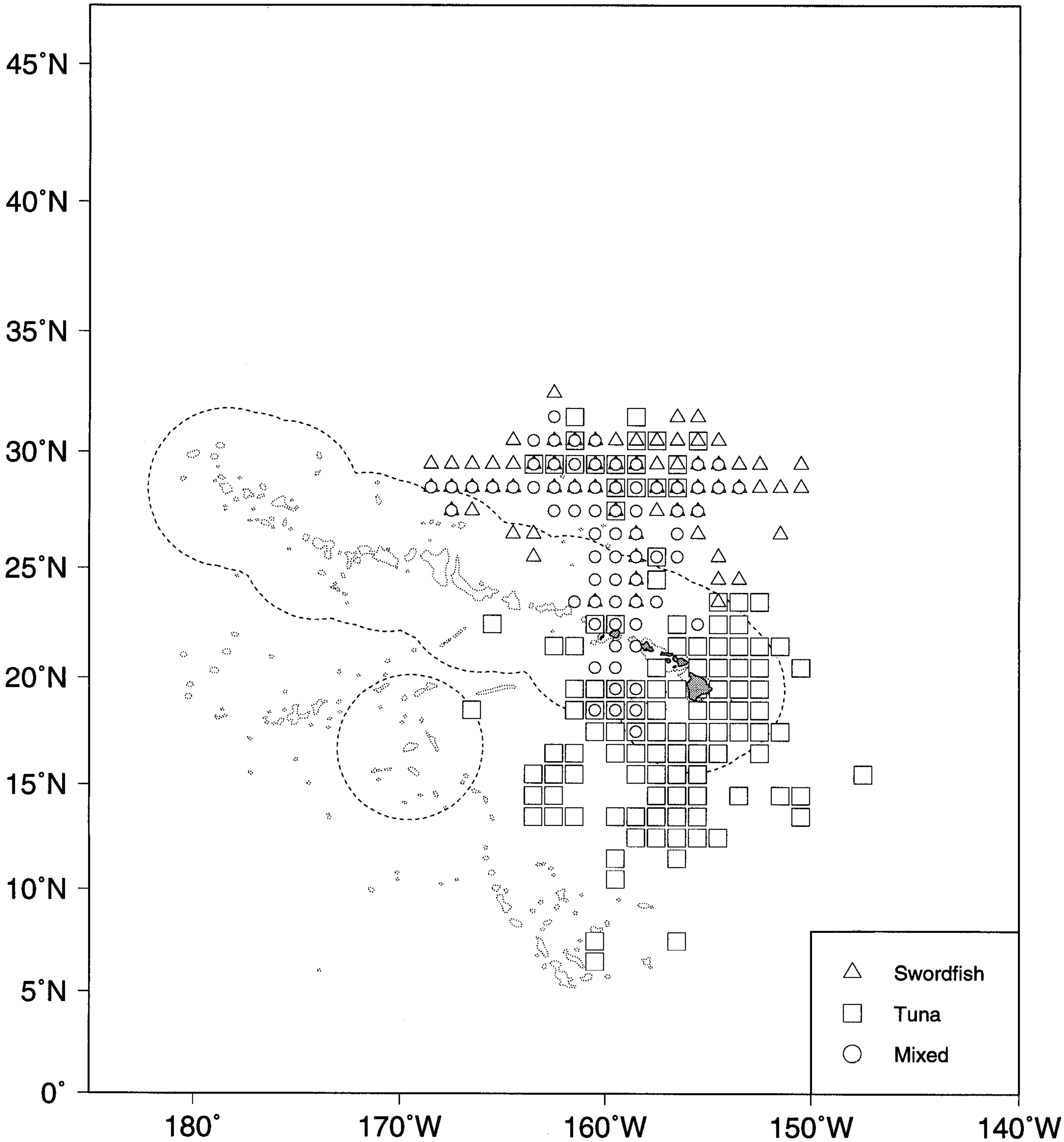
Appendix Figure 2

Hawaii Longline Fishery - March



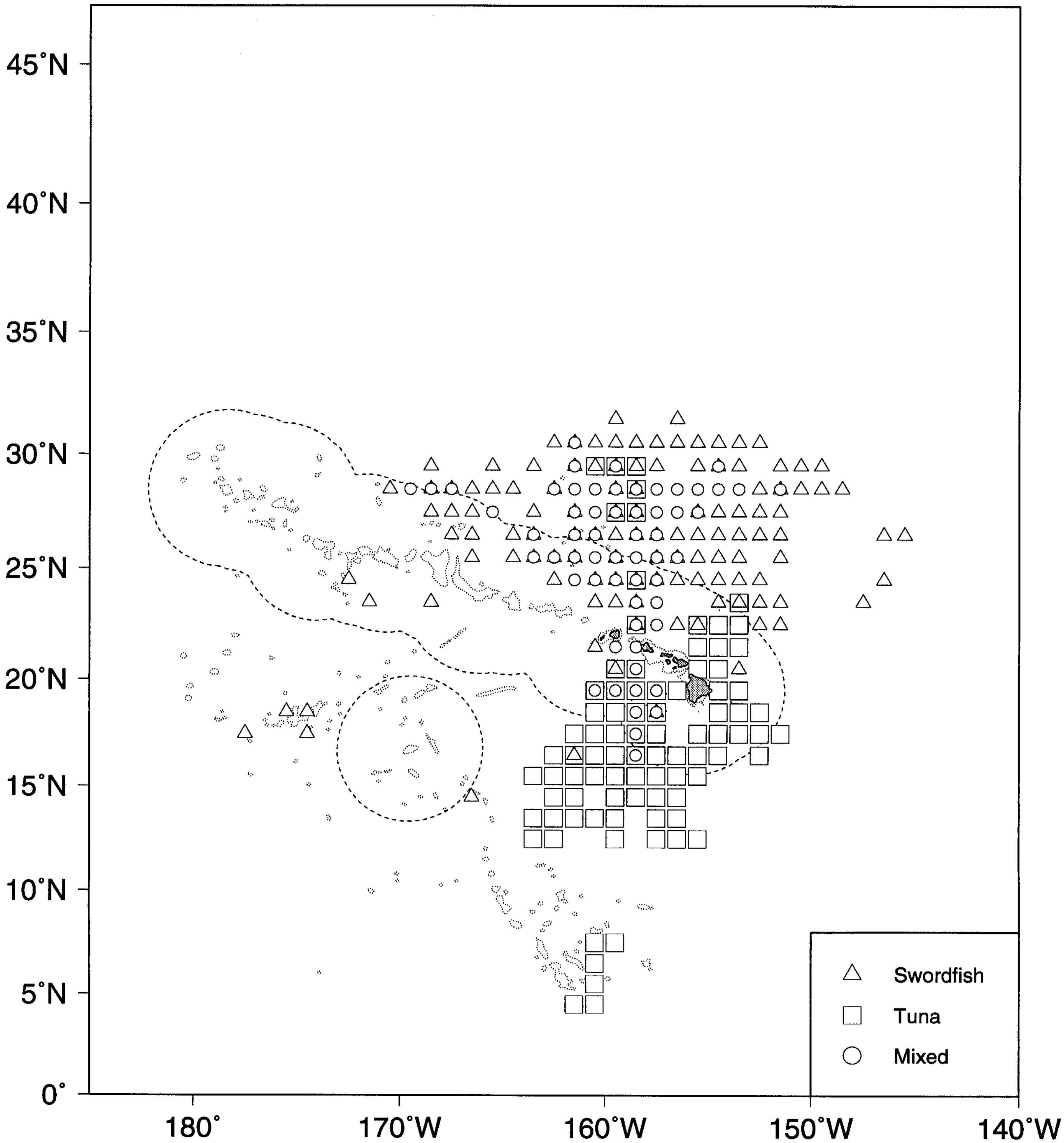
Appendix Figure 3

Hawaii Longline Fishery - April



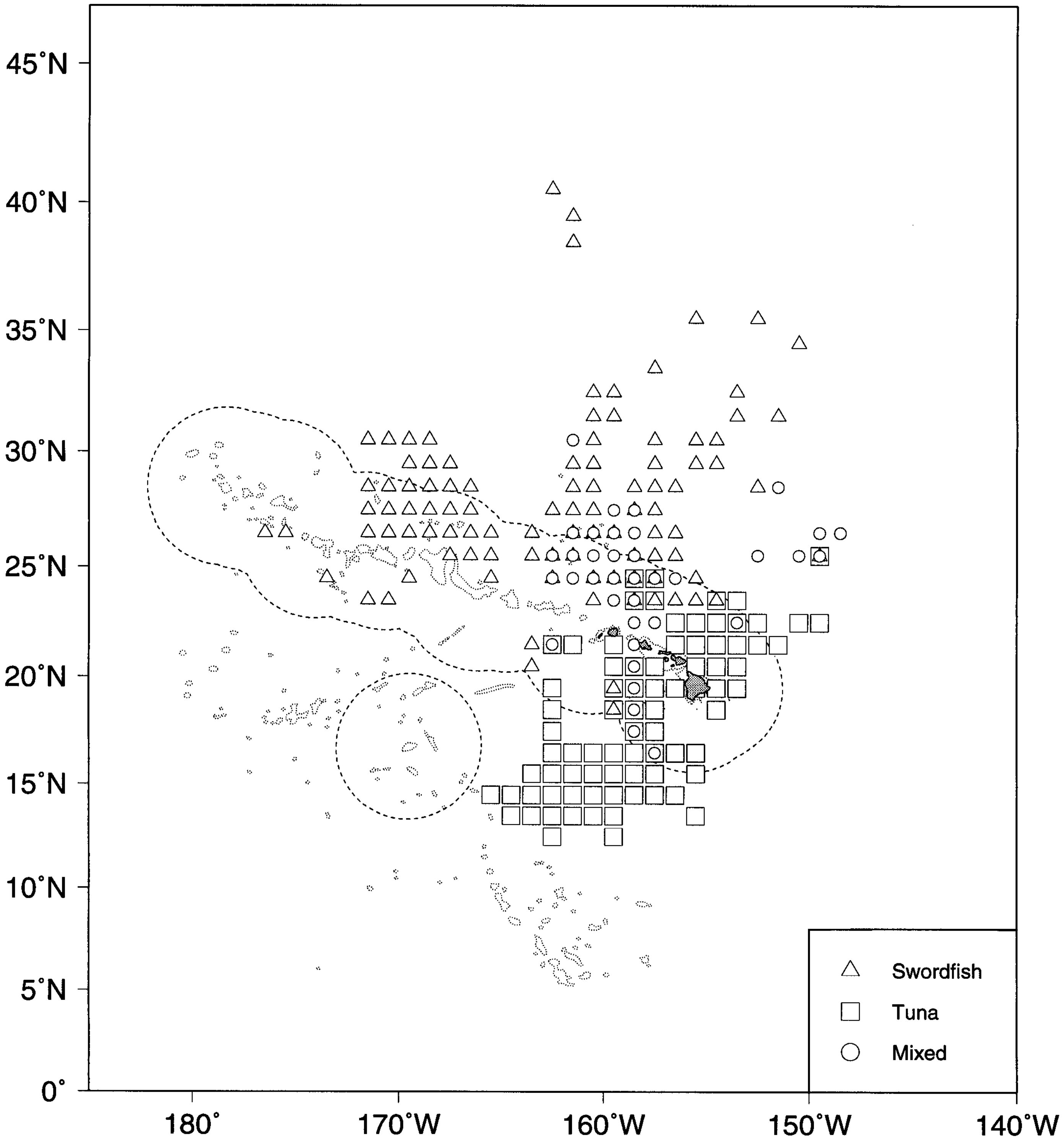
Appendix Figure 4

Hawaii Longline Fishery - May



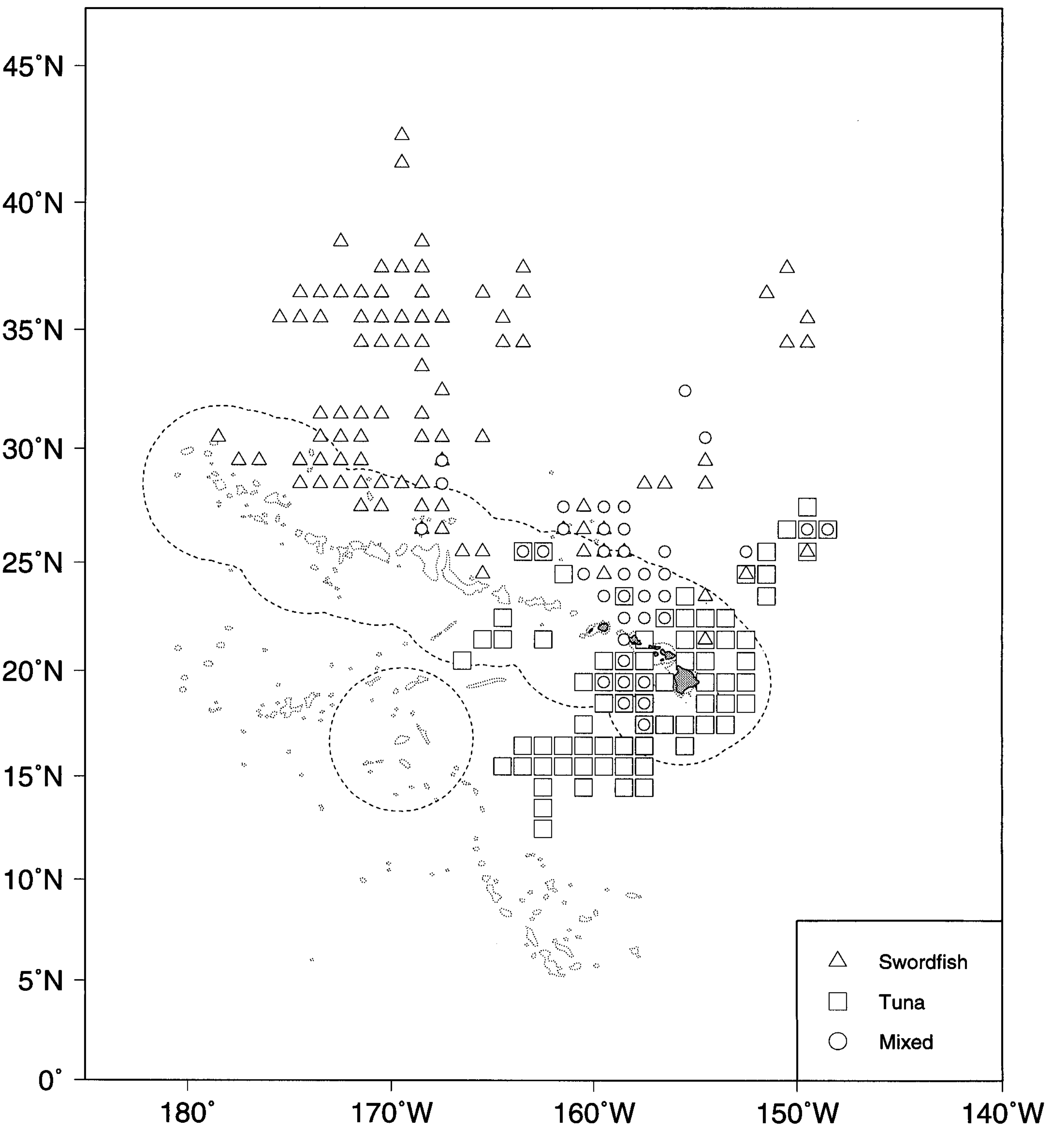
Appendix Figure 5

Hawaii Longline Fishery - June



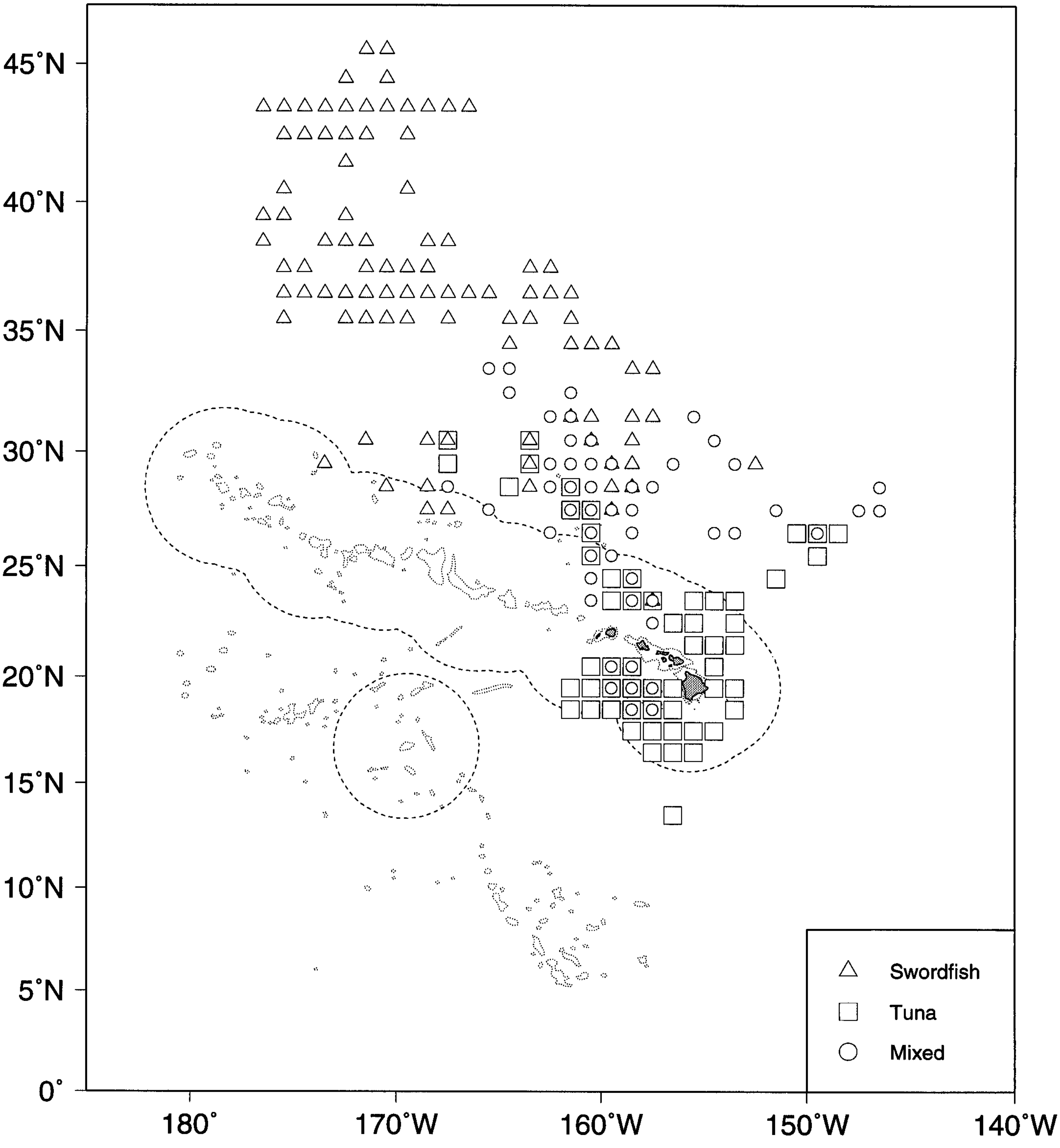
Appendix Figure 6

Hawaii Longline Fishery - July



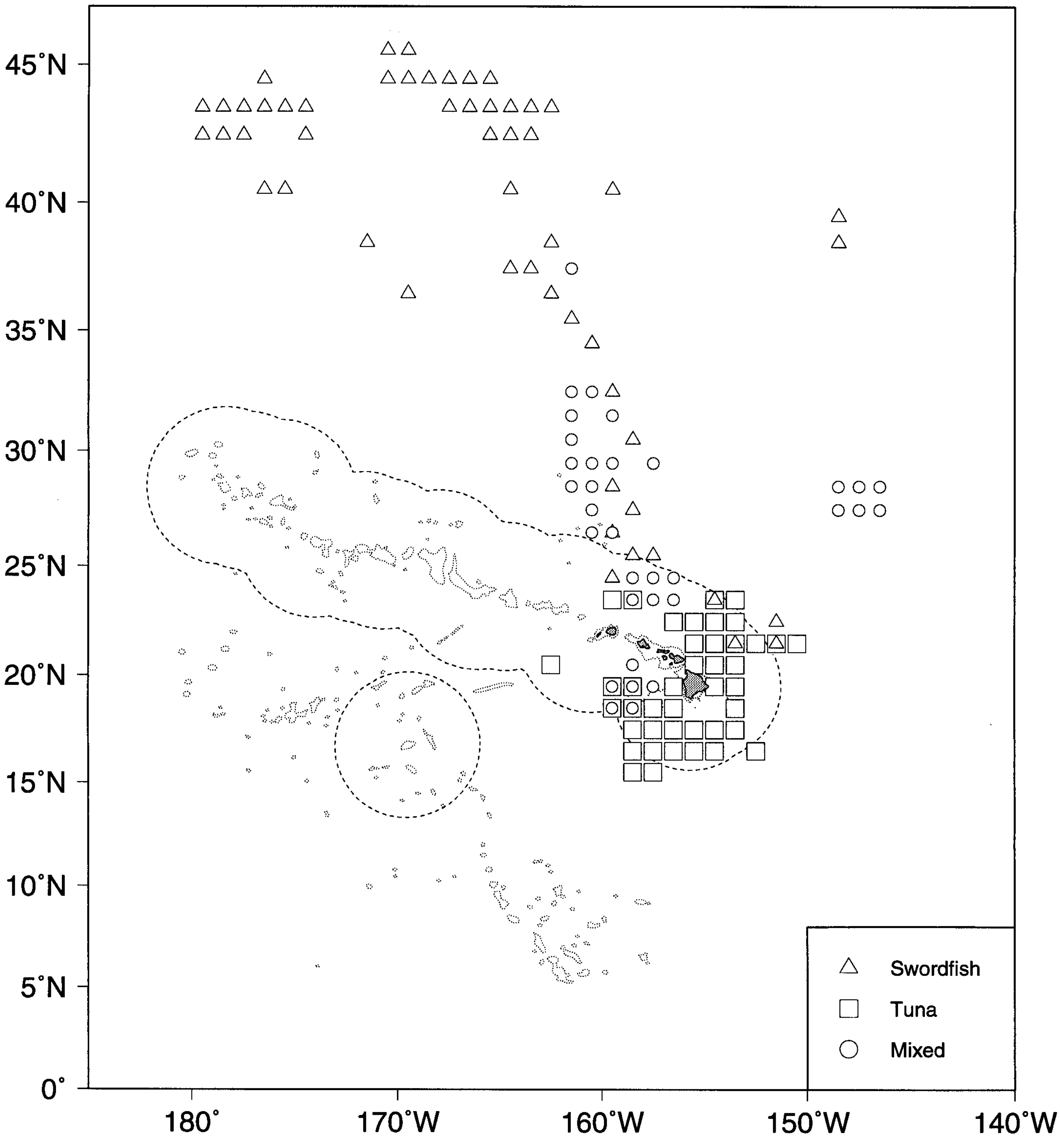
Appendix Figure 7

Hawaii Longline Fishery - August



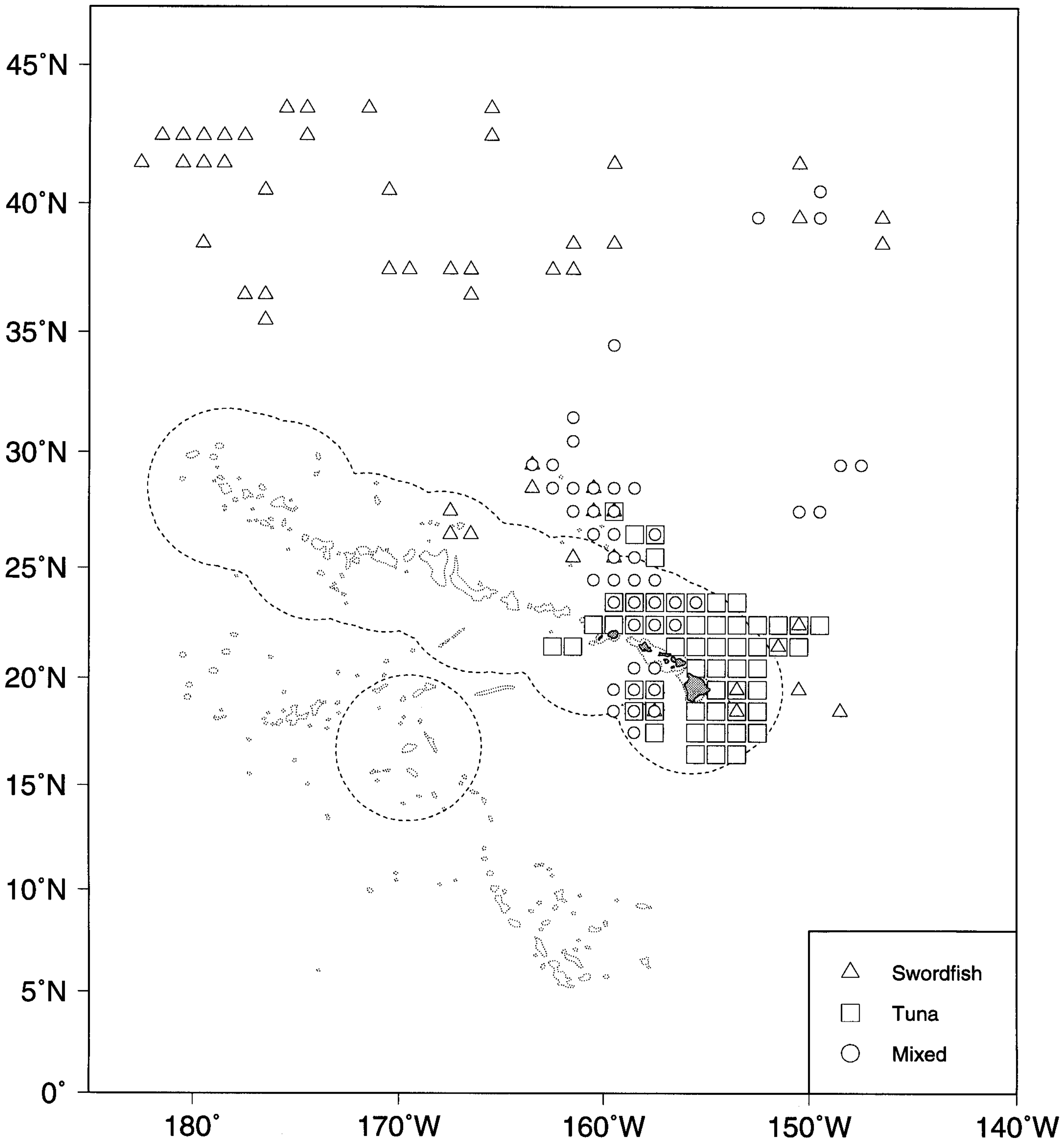
Appendix Figure 8

Hawaii Longline Fishery - September



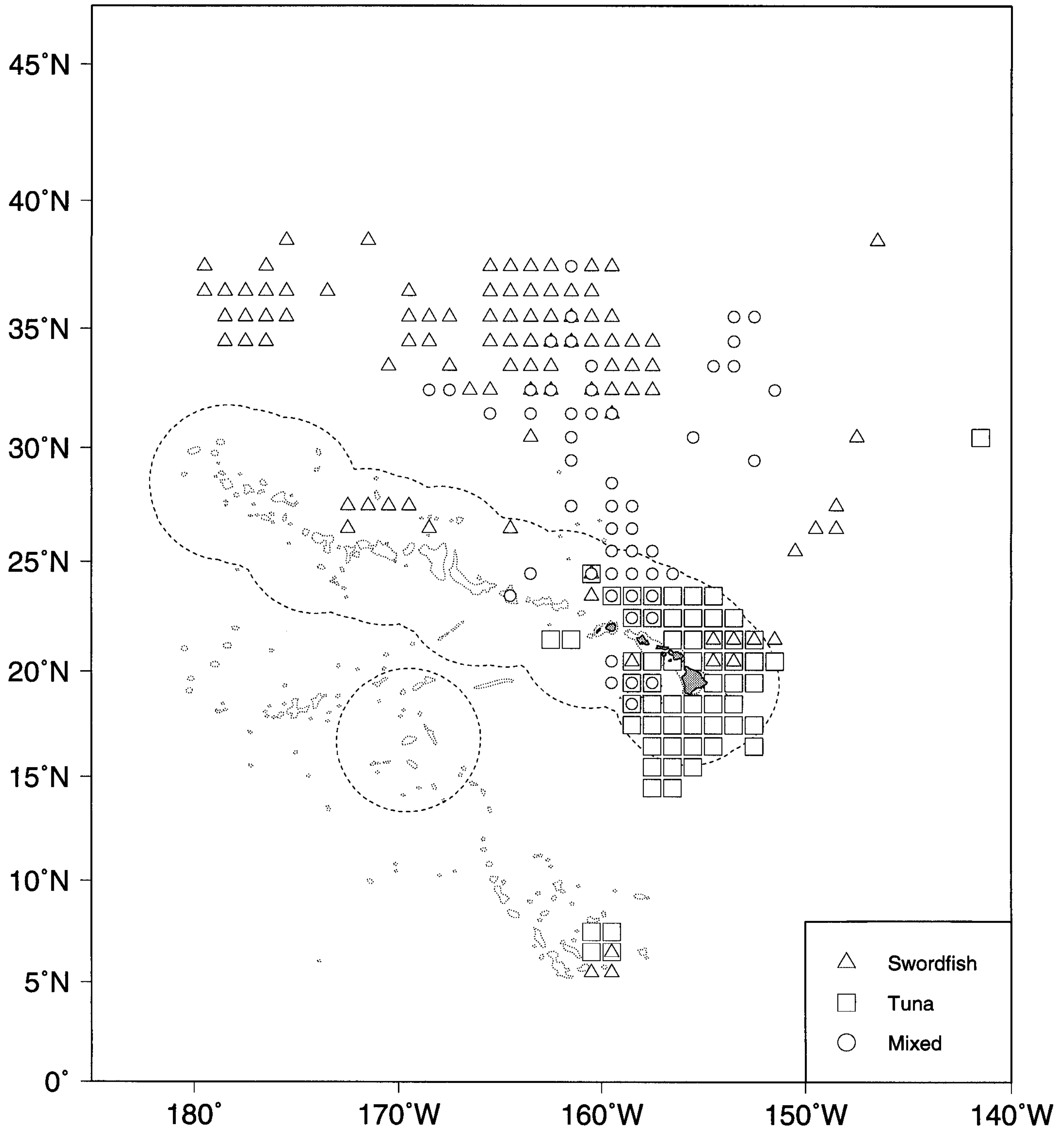
Appendix Figure 9

Hawaii Longline Fishery - October



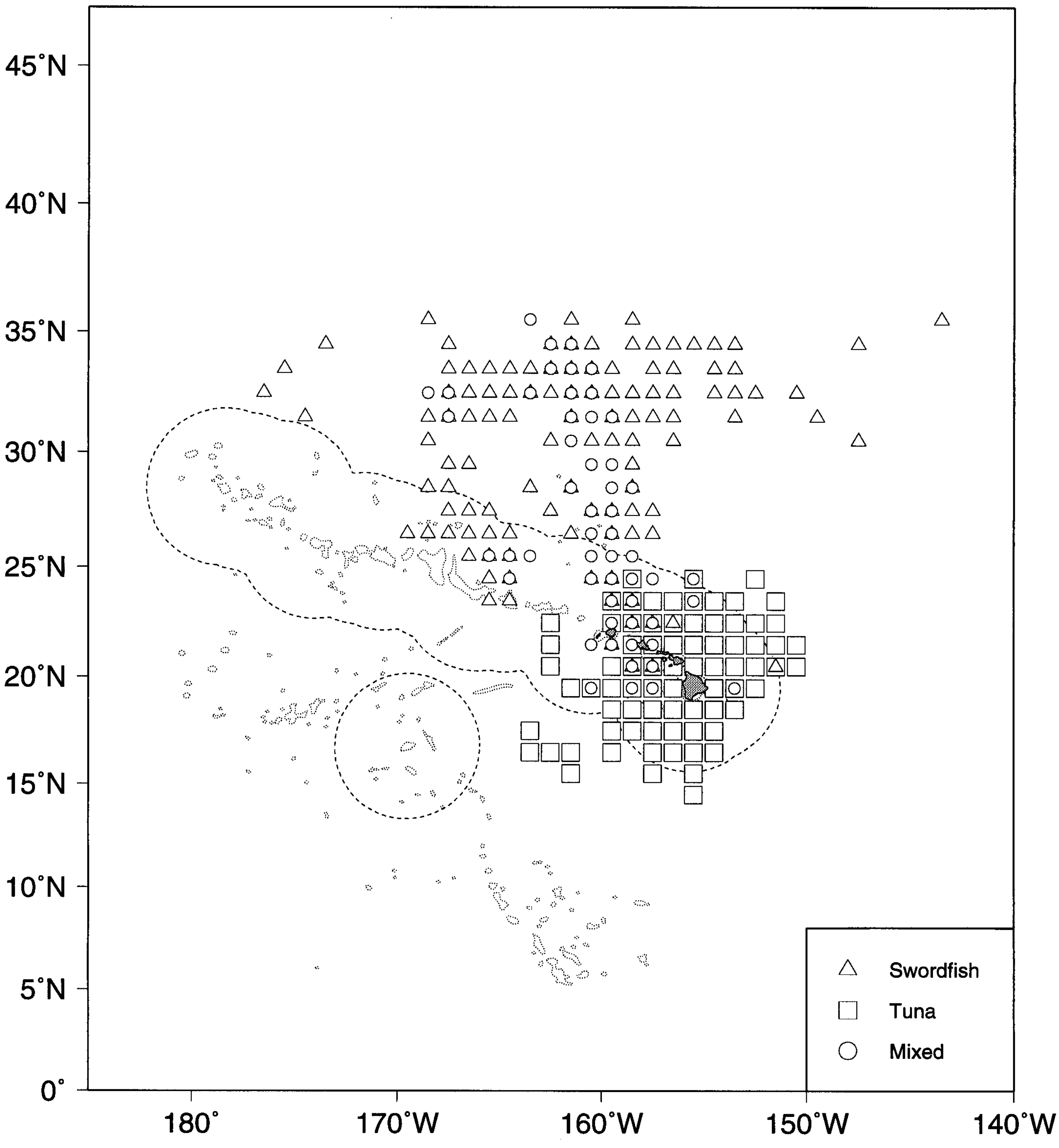
Appendix Figure 10

Hawaii Longline Fishery - November



Appendix Figure 11

Hawaii Longline Fishery - December



Appendix Figure 12

RECENT TECHNICAL MEMORANDUMS

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NOAA-TM-NMFS-SWFSC-180 Report of ecosystem studies conducted during the 1992 eastern tropical Pacific common dolphin survey on the research vessels *David Starr Jordan* and *McArthur.*
V.A. PHILBRICK, P.C. FIEDLER, S.B. REILLY, R.L. PITMAN, and L.T. BALLANCE
(April 1993)

181 Summary of cetacean survey data collected between the years of 1974 and 1985.
T. LEE
(May 1993)

182 The Hawaiian monk seal and green turtle at Pearl and Hermes Reef, 1990-1991.
M.A. FINN, J.R. HENDERSON, B.L. BECKER, and T.J. RAGEN
(May 1993)

183 Summary of 1989 U.S. Tuna-Dolphin Observer Data.
A.R. JACKSON
(July 1993)

184 Report of ecosystem studies conducted during the 1991 California coastal marine mammal survey aboard the research vessel *McArthur.*
V.A. PHILBRICK, P.C. FIEDLER and S.B. REILLY
(July 1993)

185 Report of the two aerial surveys for marine mammals in California coastal waters utilizing a NOAA DeHavilland Twin Otter Aircraft March 9-April 7, 1991 and February 8-April 6, 1992.
J.V. CARRETTA and K.A. FORNEY
(September 1993)

186 The biology and population status of marine turtles in the North Pacific Ocean.
K.L. ECKERT
(September 1993)

187 Hawaiian monk seal observations at French Frigate Shoals, 1985.
J.J. ELIASON, J.R. HENDERSON, and M.A. WEBBER
(September 1993)

188 "Best" abundance estimates and best management: Why they are not the same.
B.L. TAYLOR
(October 1993)

189 Fishery interaction between the tuna longline and other pelagic fisheries of Hawaii.
R.A. SKILLMAN, C.H. BOGGS, and S.G. POOLEY
(October 1993)