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DISTRIBUTION AND ABUNDANCE OF ODONTOCETE SPECIES IN HAWAIIAN WATERS: PRELIMINARY RESULTS OF 1993-98 AERIAL SURVEYS

by

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ADMINISTRATIVE REPORT LJ-00-14C

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Introduction

The abundance and distribution of marine mammals around the main Hawaiian Islands are not well understood. Most of the documented sightings have come from survey-based or incidental observations made primarily in inshore waters (e.g., Shallenberger 1981; Balcomb 1987; Leatherwood et al. 1988; Tomich 1986), from stranding data (Nitta 1991) or from monitoring of fisheries (Nitta and Henderson 1993).

The aerial surveys reported here were performed during a five-year period from 1993-98 as part of the Acoustic Thermometry of Ocean Climate Marine Mammal Research Program (ATOC MMRP). The purpose of the surveys was to assess the distribution and abundance of all marine mammals within approximately 25 nautical miles (46 km) of the major Hawaiian Islands, in order to assess possible effects of the ATOC transmissions (Note: the ATOC source was operational only during the 1998 field season). During 1993, 1995 and 1998, surveys were performed throughout waters adjoining the eight major Hawaiian Islands. Though sightings of all marine mammal species were recorded, the primary focus was on the two endangered cetacean species, humpback whales (*Megaptera novaeangliae*) and sperm whales (*Physeter macrocephalus*) (ARPA 1995). This report covers distribution and abundance for the odontocete species seen only. Results for humpback whales will be summarized in a separate report, and the single sighting of a fin whale (*Balaenoptera physalus*) has previously been reported (Mobley et al. 1996).

Methods

Field methods

Aircraft and Equipment

Survey aircraft (1993: two single-engine Cessna 172s; 1995: twin-engine Cessna Skymaster; 1998: twin-engine Partenavia Observer) were equipped with Collins ALT 50A radar altimeters and Morrow Apollo GPS receivers connected to a laptop computer. Data acquisition software was developed by Grotefendt Photogrammetry Inc. GPS positions were automatically recorded at 30-sec intervals and were recorded by manual trigger whenever a sighting was made. Sighting angles to target pods were measured using Suunto (Model PM-5) hand-held clinometers with analog display calibrated to whole degrees. These angles, in combination with the altitude data, allowed for the estimation of perpendicular distance from the transect line to the sighting. Given the average recorded altitude of 238.5 m (sd = 52.7 m), errors of $\pm$ one degree of angle yielded theoretical distance estimation errors of from 9.6 m at the maximum sighting angle of 70 degrees from horizontal (corresponding to the closest visible point), to 3,493 m at the maximum effective distance of approximately 2 nmi (3.7 km; sighting angle of 3 degrees $\pm$ one degree).

Scheduling of Flights

During each of the three years, 1993, 1995 and 1998 (hereafter referred to as 1993-98 surveys), four surveys of the waters adjoining the major Hawaiian Islands were performed during February to April, spaced approximately one to two weeks apart (Table 1). A full survey typically required four separate flights across four days to cover all island regions.

Trackline Design

Survey tracklines were designed according to distance sampling theory (Burnham et al. 1980; Buckland et al. 1993). The surveys followed north-south systematic lines spaced 14 nm (26 km) apart, with random lines connecting the endpoints. For the waters north of Kauai (location of ATOC sound source) the lines were spaced 7 nm (13 km) apart with one or two lines spaced 3.5 nm (6.5 km) apart in the immediate vicinity of the ATOC source (Figures 1-3). Random longitudinal starting points were used so that the exact trackline configuration of each of the four surveys varied. The systematic lines continued north and south to a point 7 nmi past the 1000 fathom limit with random lines connecting endpoints. Portions of the survey where observers were off-effort (i.e., when over land or above designated altitude) were designated as dead-head lines and were not used in abundance analyses.

Personnel

Survey staff consisted of three individuals, including two observers (one on each side of the aircraft) and one data recorder, in addition to the pilot. During the surveys, staff were generally rotated through each of the major regions to help randomize observer influences. All survey staff were experienced in distance sampling techniques with a minimum of two seasons prior survey experience.

Data Protocol

One observer searched on each side of the aircraft and communicated verbally with a data recorder seated next to the pilot. When a sighting occurred, observers called out data in the following order: number of individuals, calf (if present), species, angle to sighting, and reaction (i.e., whether pod members appeared to react to plane). These data were manually noted by the data recorder. Additionally, environmental data were recorded at the start of each leg or when conditions changed, using designated codes (Appendix). Each observer called out individual information regarding glare and visibility, and Beaufort sea state was recorded as a single value applying to the entire viewing area. The automated data, which indicated real time, latitude and longitude from the GPS receiver, and altitude (to the nearest foot) from the radar altimeter, were automatically written onto the hard disk of the laptop computer, and onto a 3.5" floppy disk as back-up. The manually-written data were entered into an ASCII file and later merged with the computer-written data.

Identification of species of a given sighting was made only when diagnostic features could be clearly identified. In cases where such features were not clearly visible, or when there was a dispute over species identity, the sighting was recorded as an unidentified dolphin, whale, or cetacean. In some cases, genus could be identified, but not individual species, for example with *Stenella* spp. In the latter case, they were recorded as unidentified *Stenella* spp. Whales of the genus *Mesoplodon* were seen several times. Only Blainville's beaked whale (*Mesoplodon densirostris*) has been reported in Hawaiian waters (Leatherwood et al. 1988; Tomich 1986), but identifying characteristics were not always visible and some of the sightings were therefore recorded as *Mesoplodon* spp. in the field. Because *M. densirostris* is the only species of this genus known to occur in Hawaiian waters, these unidentified *Mesoplodon* whales were considered to be *M. densirostris* for the abundance analyses. Group size was estimated conservatively by recording the minimum number of animals counted. For larger groups, this was typically performed by leaving the transect and circling over the group until a minimum count was obtained.

Analytical Methods

Abundance Estimation

Abundance analyses were performed using the program DISTANCE (Release 3.5; Thomas et al. 1998) following line transect methodology (Buckland et al. 1993). The program DISTANCE estimates density and abundance for each species in a specified stratum using the general formulae:

$$D = \frac{n \cdot f(0)}{2 \cdot L} \quad (1),$$

$$N = D \cdot A \quad (2),$$

where	D	=	estimated density,
	n	=	number of individuals,
	$f(0)$	=	estimated probability density evaluated at zero perpendicular distance,
	L	=	total length of transect line,
	N	=	estimated abundance,
	A	=	total area surveyed.

Global data truncation

State conditions clearly affected the sighting probability beyond a Beaufort 3 (Figure 4), and therefore survey effort and sightings made during sea states greater than 3 on the Beaufort scale were not included in the analyses. Visibility conditions were also rated on a five-point scale (excellent, good, fair, poor, unacceptable), reflecting a combination of glare and atmospheric visibility (Appendix). Because the sightability of cetaceans can be greatly reduced by glare, data gathered in poor and unacceptable conditions were also eliminated from the data set for abundance analyses. Occasionally, only one side of the aircraft had unacceptable conditions; in these cases, sightings for that side of the aircraft were excluded and the survey effort was adjusted by dividing the number of kilometers flown in half. This adjustment affected less than 5% of the total survey effort .

Perpendicular sighting distances

Due to downward visibility limitations of the aircraft, only sightings to a maximum of 70 degrees from horizontal were possible. This created a theoretical blind area of approximately 100 m on each side of the aircraft (at 245 m altitude). However, inspection of perpendicular distance data suggested that the functional blind area was about 200 m on each side of the transect line (Figure 5). Therefore all sightings within 200 m of the transect line were truncated prior to estimating the detection function (i.e. a left-truncated analysis was performed in DISTANCE). This introduces considerable uncertainty in the abundance estimates, because the behavior of the detection function near the transect line must be modeled without actual perpendicular distance data.

To reduce the likelihood of selecting inappropriate models, only the Hazard rate, half-normal and uniform models (with adjustments) were considered when fitting the detection function. These three models have been shown to provide good fits to cetacean aerial survey data when sightings on and near the transect line were possible (Forney et al. 1995; Barlow et al. 1997; Calambokidis et al. 1997; Kingsley and Reeves 1998; Forney 1999). Akaike's information criterion (AIC) was used as the primary model selection criterion, but the selected models also were compared to previously published ones to ensure that the model fit near the transect line was reasonable. The estimated probability of detection at 200m, g(200), was used as a quantitative comparative measure, and the models were also compared visually. Extreme functional shapes or values of g(200) that did not fall within those found in the published literature were avoided; in all cases the models selected in this analysis represented an intermediate functional shape that was consistent with previously published fits of detection functions for aerial surveys. The abundance estimates derived in this analysis are therefore expected to have considerable uncertainty, but should not be systematically biased by an extreme detection function shape and corresponding f(0) value.

Pooling and stratification for estimating f(0)

Because the numbers of odontocete sightings were typically small (range: 1 to 50 groups), species were pooled based on considerations of group size, body size, behavior, and depth strata, as described by Forney and Barlow (1993). Species whose detection functions were not significantly different (Kolmogorov-Smirnov test, α = 0.05) were placed in the same group. This resulted in the following four species groups: Small Cetaceans, *Tursiops/Steno*, Medium Cetaceans, and Large Cetaceans (Table 2). The perpendicular distance distributions for *Tursiops* and *Steno* species were sufficiently different (p=0.03) from those of small and medium cetaceans to warrant placement in a separate group. Stratification by group size and water depth category was investigated for each species group, and was chosen over an unstratified analysis if AIC was lower. The three water depth categories were 1) <100 fathoms (<183m), 2) 100-1,000 fathoms (183-1, 830 m), and 3) >1,000 fathoms (>1,830 m).

Because the period of this study (Jan-Apr) corresponded with peak densities of humpback whales (Herman et al. 1980; Baker and Herman 1981; Mobley et al. 1994; Mobley et al. 1999), the vast majority of large cetacean sightings were of this species. Although this report focuses only on odontocete species and no humpback whale abundance estimate is included, insufficient sightings of sperm whales were available to estimate the detection function separately for this species. Humpback whale sightings were therefore included when estimating the large whale detection function; however, because sperm whales were only seen in depth strata 2 and 3, humpback whale sightings were only included if they were made within these two strata. This should minimize any potential differences in sighting probability caused by breeding activities of humpback whales in shallow waters. This restriction also effectively increased the proportion of sperm whales among the large cetacean sightings used to estimate the detection function, and therefore is expected to provide a more accurate abundance estimate for sperm whales.

Buckland et al. (1993) recommended horizontal truncation to remove 5-15% of sightings that are farthest from the trackline. Analysis of the sighting patterns for each group of cetaceans indicated that detectability of small and medium-sized cetaceans decreased substantially beyond 0.8 km from the trackline. The data also exhibited rounding error at farther distances. Thus, observations of these groups beyond 0.8 km were eliminated from further analyses (8.6%-19.0% of the sightings in each group). For large cetaceans, there was no similar decrease in detectability, but rounding error was severe beyond 2.0 km and the distances were not considered reliable. Therefore a truncation distance of 2.0 km was used for this group. This eliminated 39% of the sightings, but still allowed 250 large whale sightings to be used for estimation of f(0).

Results and Discussion

Effort and Sightings

The surveys covered an area of 71,954 km^2, which included shallow near-shore waters and deep pelagic regions (Figures 1-3). Depth stratum 1 (<100 fathoms; <183m) included 7,561 km^2, Depth stratum 2 (100-1,000 fathoms; 183-1830m) included 30,266 km^2, and Depth stratum 3 (>1,000 fathoms; >1830m) included 34,127 km^2. A total of 13 species of odontocete cetaceans were sighted, comprising 359 groups (Table 3). Of these sightings, 12 species (198 groups) were observed in acceptable visibility and Beaufort conditions and were included in the abundance estimates. Two sightings of *Kogia* spp. occurred in unacceptable viewing conditions and were excluded from abundance analyses.

Species Distribution

Figures 6 - 13 show maps of the major Hawaiian Islands with locations of all sightings by species based on the aircraft's GPS position. In general, the odontocete species tended to be seen with greater than expected frequency in the middle depth stratum (Figure 4), though the difference was not significant [$\chi^2_{2df} = 2.57$, $p>0.05$]. *Mesoplodon* spp. and sperm whales showed a greater preference for the deepest stratum (77% of 13 sightings and 83% of 29 sightings, respectively). As shown (Figure 12), sperm whales were generally seen in the outer 5% of survey effort.

Effects of Sea State on Sightings

Sea state conditions are known to significantly affect sighting probabilities (Buckland et al. 1994). Sea state conditions during the 1993-98 statewide surveys were generally good, with an average sea state of 2.9 (sd= 1.19); however, sightings did not occur uniformly throughout all sighting conditions. Observed frequencies of sightings tended to fall below expected frequencies beyond a Beaufort sea state of 3 (Figure 4). Chi-square test of independence showed the overall differences between observed and expected frequencies of sightings by sea state to be significant [$\chi^2_{5df} = 12.21$, $p<.05$]. Therefore, only effort and sighting data for Beaufort sea states 0-3 were included for abundance estimation.

Abundance Estimates

Twelve species were sighted frequently enough to warrant abundance estimation (Table 3). Additionally, five groups were sighted and identified to the generic level as *Stenella* spp., 35 groups were identified only as dolphins, two groups were confirmed as beaked whales of unidentified genera, and four groups could not be identified beyond the level of cetacean. The *Stenella* spp. and unidentified dolphin sightings were analyzed with the small cetacean group, while the unidentified beaked whale and unidentified cetacean groups were grouped with the medium cetaceans to estimate the probability density function (f(0)).

The detection model and stratification option with the lowest Akaike Information Criterion was selected for abundance estimation (Table 2). For medium cetaceans, AIC was higher using group size strata than for the unstratified analysis, and therefore all group sizes were pooled for analysis. Stratification by depth category, however, reduced AIC for the medium cetaceans, presumably because of heterogeneity in the depth distribution of the different species within this group. The lowest AIC was obtained using two depth strata (categories 1 & 2 pooled and category 3), and therefore, the medium cetaceans were analyzed as two groups stratified by depth. For all other species groups, unstratified analyses minimized AIC and were therefore used to estimate abundance. Shapes of the estimated probability density functions and histograms of the observed number of sightings for each of the species groups used to estimate abundance are displayed in Figure 14. All functional shapes compared favorably with published detection functions for aerial survey data using similar species groupings. Table 3 reports the sighting results and abundance estimates for each species.

Bias

There are several sources of potential bias in this study. First, the aircraft used did not permit the observers to sight cetaceans directly below the plane. In fact, the perpendicular distance data suggested that visibility was severely reduced within 200 m of horizontal distance from the trackline. Therefore, the accuracy of abundance estimation rests on the assumption that the selected model accurately described the detection function near the transect line. If the probability of detection drops off more quickly than the model estimates, then the reported abundance estimate would be an underestimate. Conversely, if the model estimates greater detection along the transect line, then the reported abundance estimate would be too high. Efforts were made during model selection to minimize the likelihood of introducing severe bias due to lack of visibility near the trackline; however, additional data collected from an aircraft with downward visibility will be required to evaluate the magnitude of this potential bias.

Cetacean abundance estimates tend to be under-representative of true population numbers, because cetaceans can only be detected at or near the surface, and many species spend considerable time at depth. This availability bias (Marsh and Sinclair 1989) can sometimes be accounted for by applying correction factors based on the proportion of time each species spends diving (Barlow 1999). However very few correction factors are available worldwide for diving cetaceans, and none are available for Hawaiian waters. In particular, the abundance estimates presented here for beaked whales and sperm whales probably underestimate the true abundance by a factor of at least two to five (see Barlow 1999). Additional data on diving patterns for these species will be required to correct for this source of downward bias.

A final source of downward bias is introduced by animals that are missed even though they are at the surface when the aircraft passes overhead. This perception bias (Marsh and Sinclair 1989) is likely to be highest under poor viewing conditions or when observers are fatigued. It also varies by individual cetacean species based on their body size and behavior. Perception bias can be corrected using data on the proportion of sightings missed, which can be obtained from studies including independent or conditionally-independent observers or using an independent observation platform (Forney et al. 1995; Laake et al. 1997). In this study, it was not possible to estimate the magnitude of perception bias, but an attempt was made to minimize its effect by including only good survey conditions in the analysis. Abundance estimates may nonetheless be biased downward by an unknown amount.

Summary & Conclusions

This report presents the first comprehensive abundance estimates for odontocetes surrounding the main Hawaiian Islands. The abundance estimates obtained in this study represent only a portion of the total populations of most, if not all, of the odontocete species, because the study area represents only a portion of their ranges, and correction factors for the proportion of animals missed were not available. Additionally, there are a number of analytical uncertainties, caused by limitations of the survey platform, which cannot be resolved without further data. It is anticipated that additional surveys using a platform with downward visibility would provide data to reduce the uncertainty in model selection, and thus improve these abundance estimates in the future. Surveys extending farther offshore and throughout the northwestern Hawaiian Islands would provide more comprehensive population estimates, but will likely require a shipboard survey platform.

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Table 1. Summary of flight dates for 1993, 1995 and 1998 surveys.

Survey No.	1993 Dates	1995 Dates	1998 Dates
1	Feb. 21, 22-24, 26	Feb. 28, Mar. 1-4	Feb. 21, 24-25, 27, Mar. 1
2	Mar. 4-6, 8	Mar. 8-11	Mar. 5-8
3	Mar. 15, 16	Mar. 18, 20, 23-25	Mar. 13-16
4	Mar. 24-26	Apr. 1-3, 7	Apr. 6-8, 17

Table 2. Species groupings, stratification and detection models selected using AIC, and resulting f(0) values (with standard error in parentheses).

Group & Species names	Stratification & Model selected	f(0)
Small cetaceans		
Melon-headed whale, *Peponocephala electra*	Uniform with 2	4.48
Spotted dolphin, *Stenella attenuata*	cosine adjustments	(1.12)
Striped dolphin, *Stenella coeruleoalba*		
Spinner dolphin, *Stenella longirostris*		
Unidentified *Stenella* spp.		
Unidentified dolphins		
Tursiops/Steno		
Bottlenose dolphin, *Tursiops truncatus*	Uniform with 2	7.44
Rough-toothed dolphin, *Steno bredanensis*	cosine adjustments	(2.55)
Medium cetaceans		
Risso's dolphin, *Grampus griseus*	Depths 1-2:	4.58
Short-finned pilot whale, *Globicephala macrorhynchus*	Half-normal	(1.06)
False killer whale, *Pseudorca crassidens*		
Blainville's beaked whale, *Mesoplodon densirostris*	Depth 3:	3.08
Cuvier's beaked whale, *Ziphius cavirostris*	Uniform with 2	(0.60)
Unidentified beaked whale	cosine adjustments	
Unidentified cetacean		
Large cetaceans		
Fin whale, *Balaenoptera physalus*	Half-normal	0.94
Humpback whale, *Megaptera novaeangliae*		(0.13)
Sperm whale, *Physeter macrocephalus*		

Table 3. Number of groups seen, number of groups included in the analysis, mean group size, density of individuals, and abundance estimates for cetaceans in the entire Hawaiian study area. Coefficients of variation (CV) and 95% confidence intervals for the overall abundance estimates are also given.

Group / Species	No. of groups sighted	No. of groups in analysis	Mean group size	Density (D)	Abund-ance (N)	CV (%)	Confidence intervals Lower 95%	Confidence intervals Upper 95%
Small cetaceans:								
Melon-headed whale	3	2	13.5	0.0021	154	88.3	24	986
Spinner dolphin	50	26	21.5	0.0443	3,184	36.5	1,581	6,415
Spotted dolphin	23	12	42.8	0.0407	2,928	45.1	1,244	6,891
Striped dolphin	2	1	20.0	0.0016	114	118.5	17	757
Stenella spp.	10	5	19.2	0.0076	547	64.6	167	1,793
Unidentified dolphin	70	35	4.8	0.0134	963	41.0	441	2,102
***Tursiops/Steno*:**								
Bottlenose dolphin	49	28	6.0	0.0103	743	55.7	265	2,088
Rough-toothed dolphin	8	4	3.3	0.0017	123	62.8	39	390
Medium cetaceans:								
Risso's dolphin	2	1	1.0	----	----	----	----	----
Short-finned pilot whale	73	42	8.4	0.0237	1,708	32.2	923	3,159
Blainville's beaked whale	7	7	2.1	0.0009	68	59.6	23	199
Cuvier's beaked whale	7	3	3.0	0.0006	43	51.2	17	111
False killer whale	21	14	5.1	0.0017	121	47.3	50	293
Unidentified beaked whale	4	2	4.0	0.0005	36	97.1	7	176
Unidentified cetacean	9	4	1.5	0.0004	30	72.3	8	107
Large cetaceans:								
Sperm whale	21	12	4.3	0.0010	66	56.0	23	192

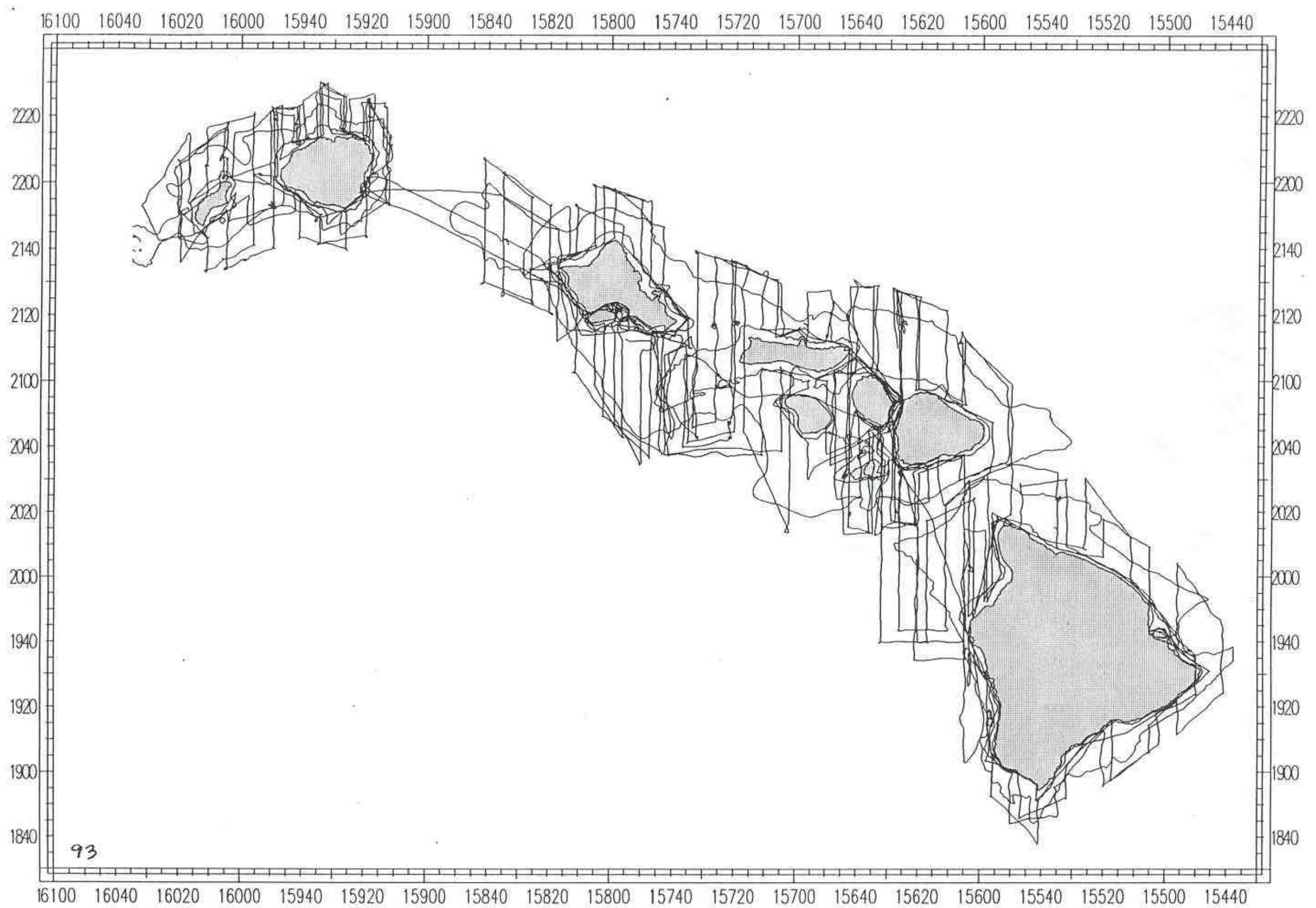

Figure 1. Transect lines flown during 1993 aerial surveys. Contours indicate 100 and 1000 fathom isobaths.

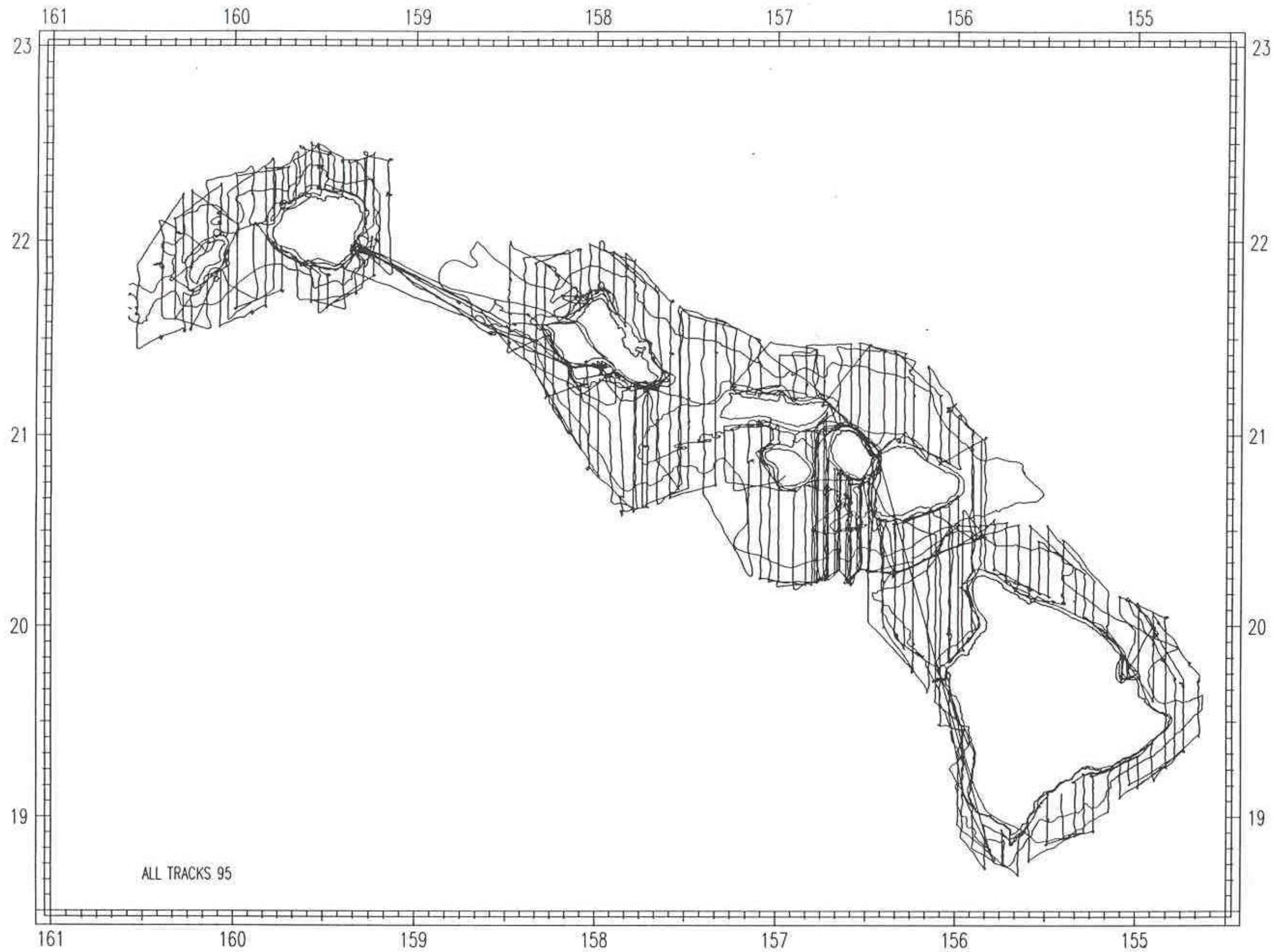

Figure 2. Transect lines flown during 1995 aerial surveys. Contours indicate 100 and 1000 fathom isobaths.

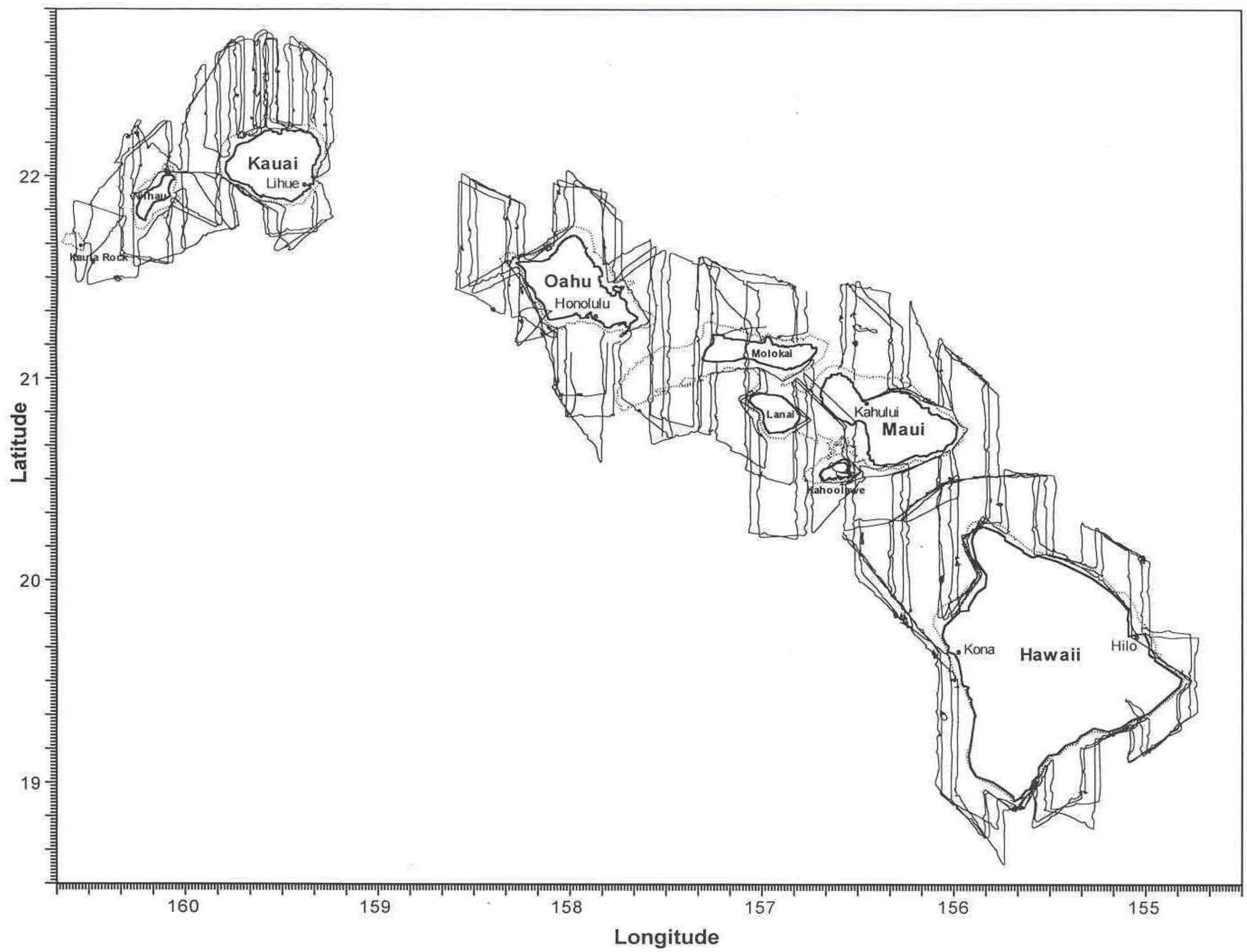

Figure 3. Transect lines flown during 1998 aerial surveys. Dotted contour line indicates 100 fathom isobath; outer edge of transect lines is approximate location of 1000 fathom isobath.

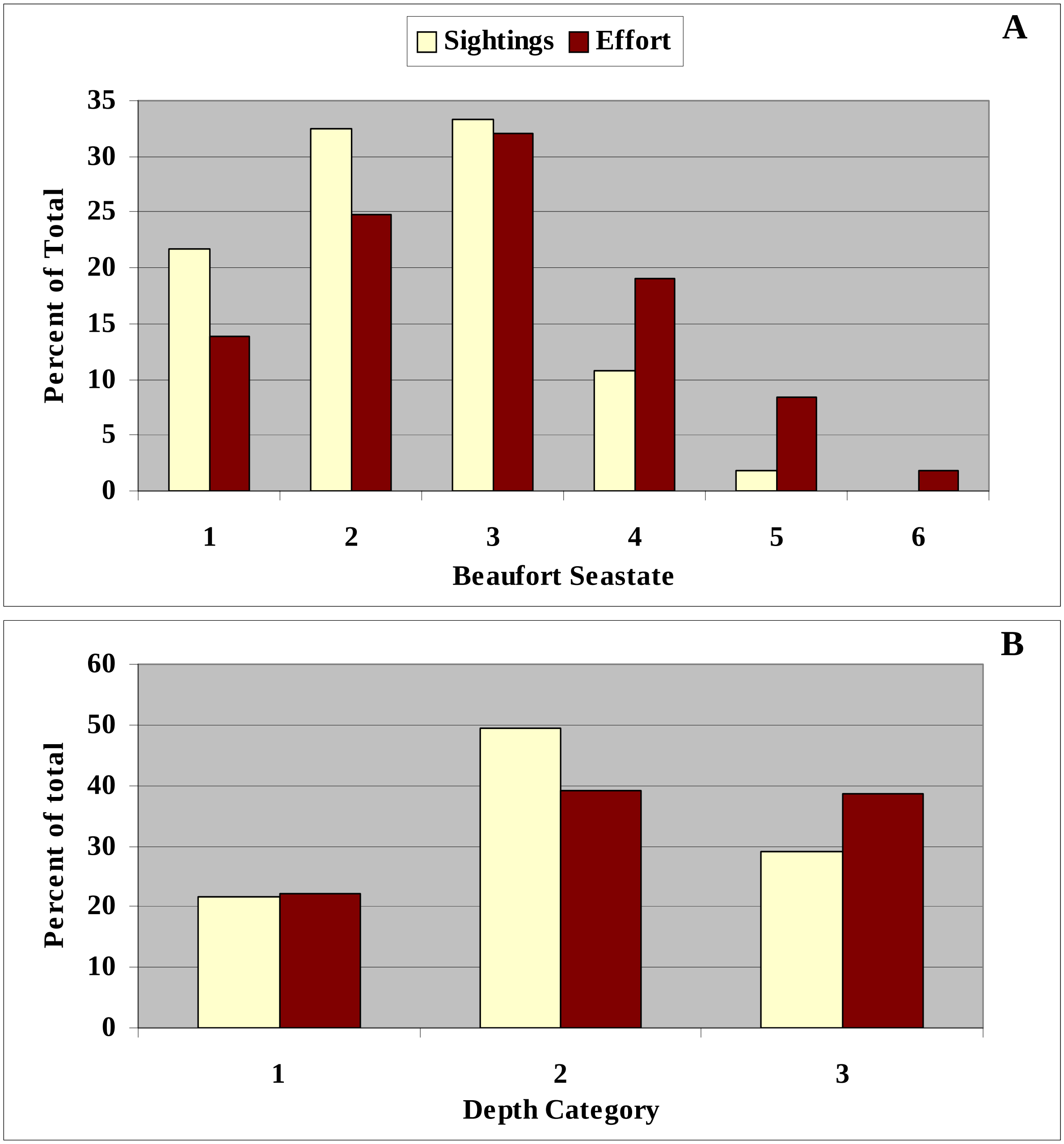

Figure 4. Percent of total 1993-98 effort and percent of sightings by (A) Beaufort sea state and (B) depth category. [Depth category key: 1= <100 fathoms (<183m), 2 = 100-1000 fathoms (183-1830m), 3 = >1000 fathoms (1830m).]

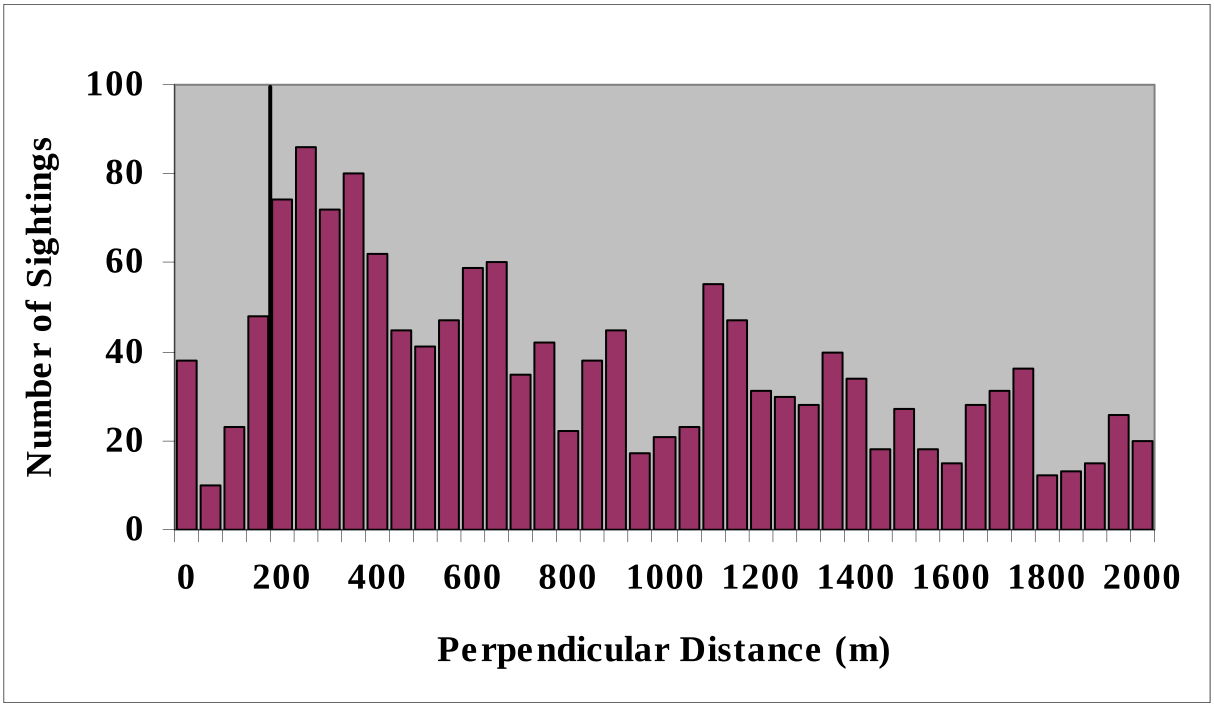

Figure 5. Perpendicular distance distribution of all cetacean sightings made within 2km of the transect line. Data were left-truncated at 200m (vertical line) because of limited downward visibility near the transect line.

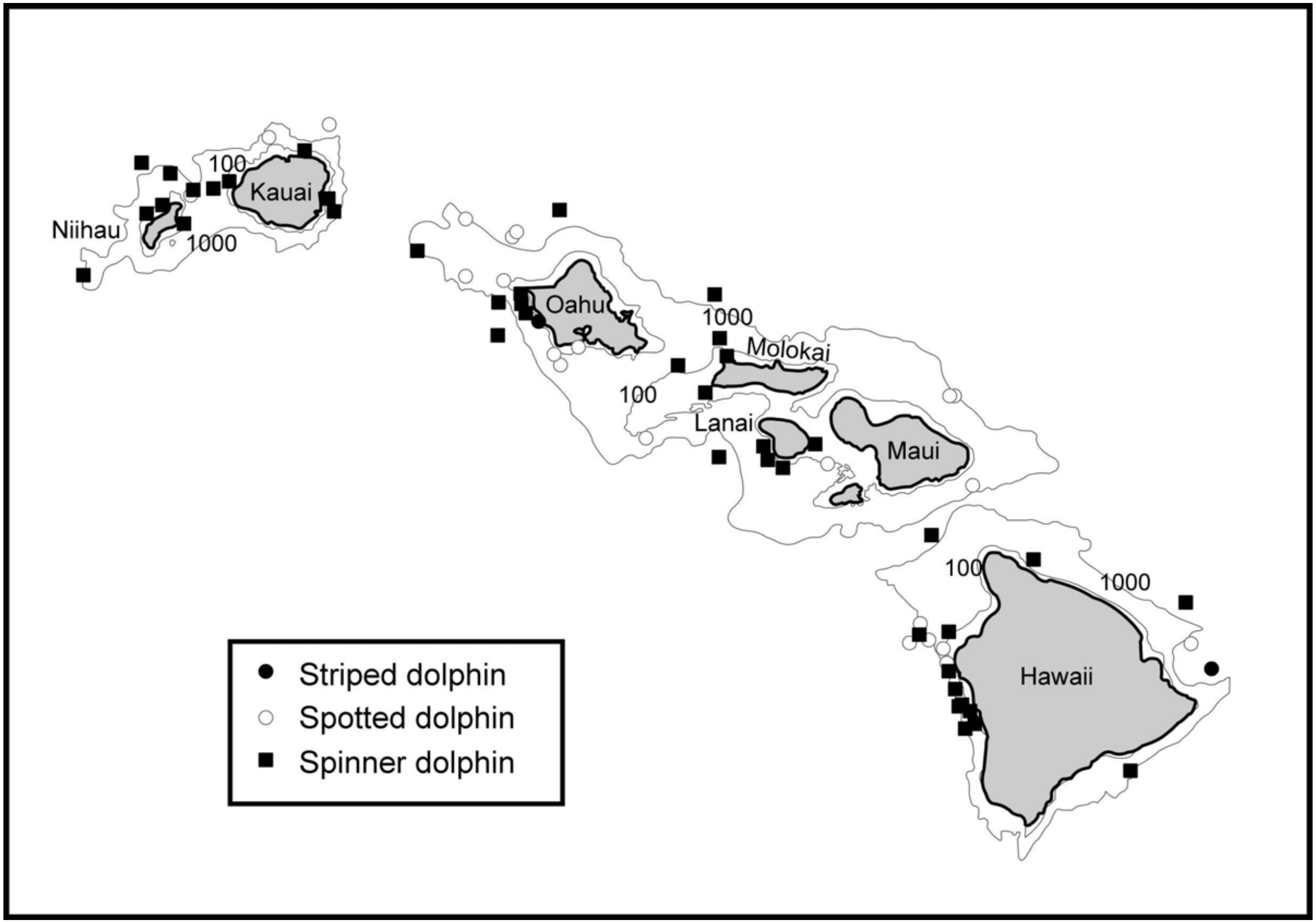

Figure 6. Sightings of striped dolphins, spotted dolphins and spinner dolphins during 1993-98 aerial surveys. Contours in fathoms.

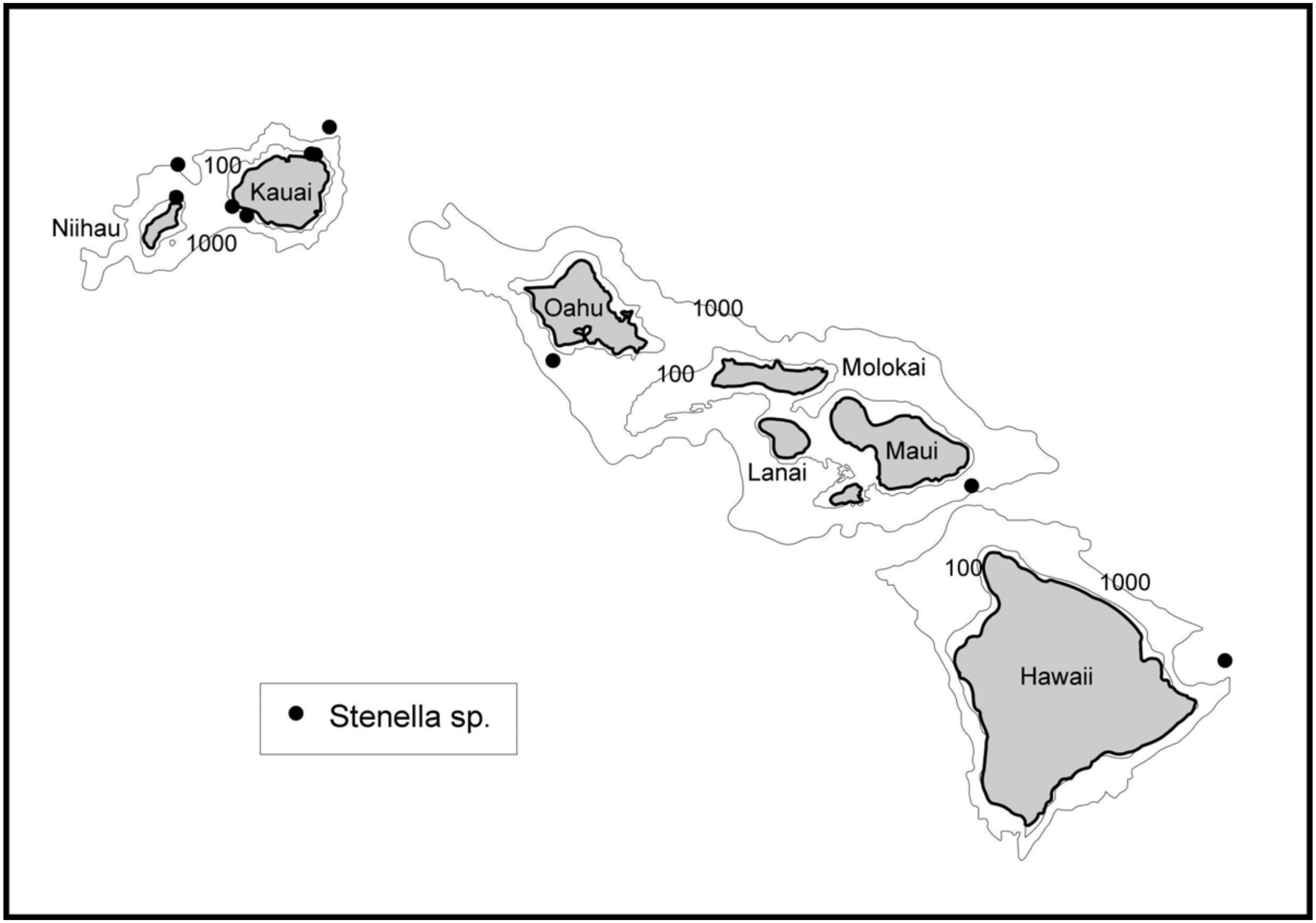

Figure 7. Sightings of unidentified *Stenella* spp. during 1993-98 aerial surveys. Contours in fathoms.

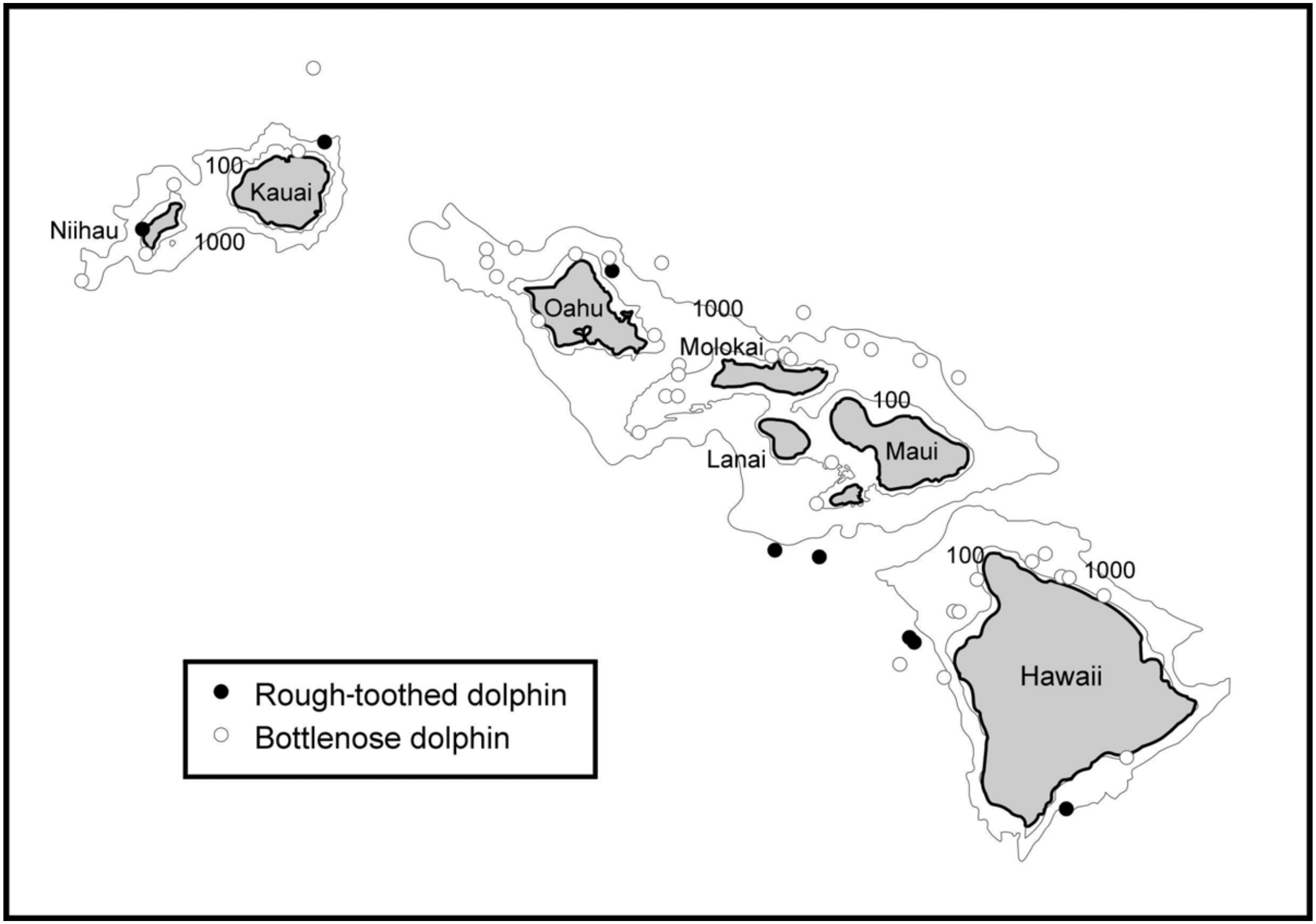

Figure 8. Sightings of bottlenose dolphins and rough-toothed dolphins during 1993-98 aerial surveys. Contours in fathoms.

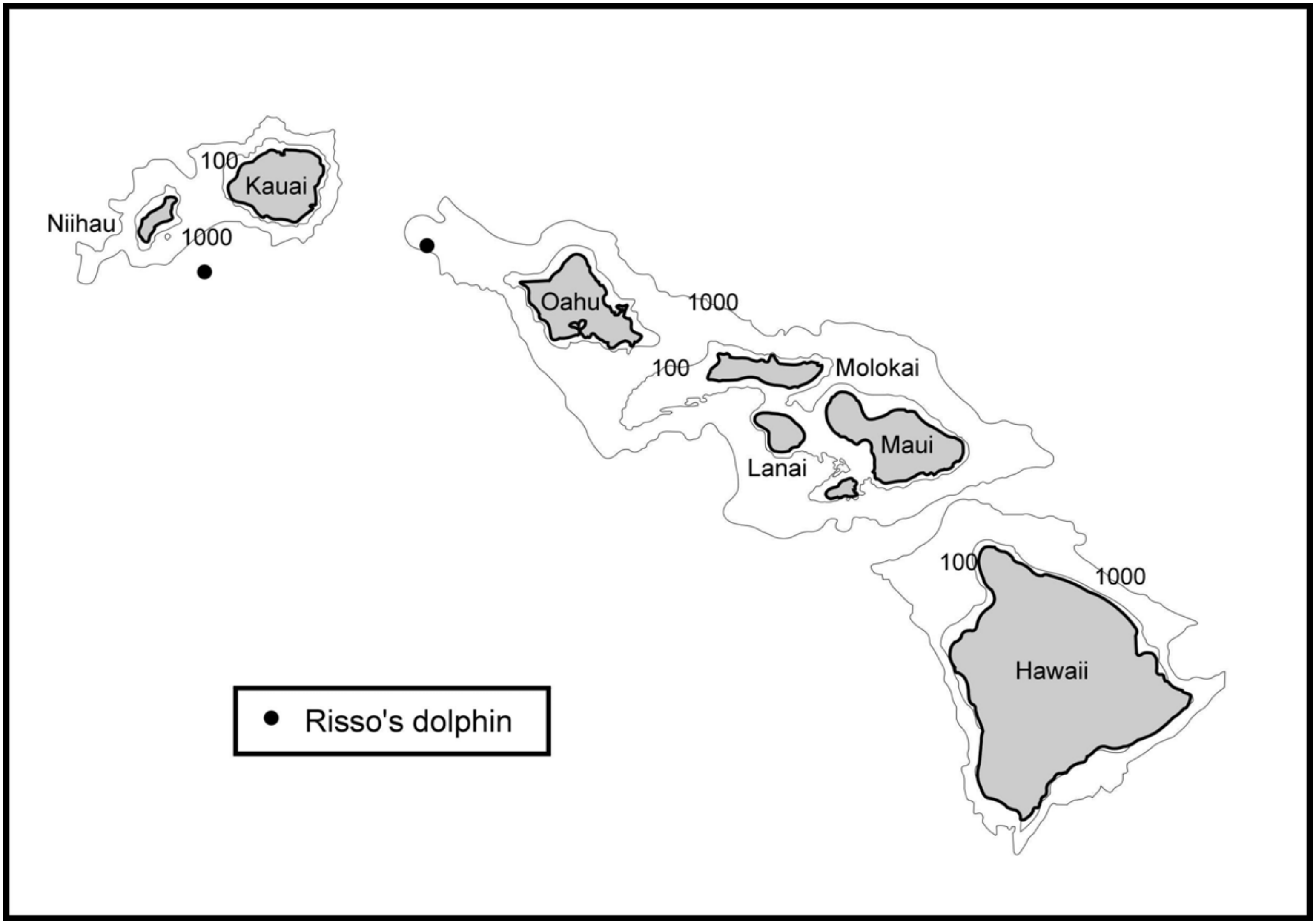

Figure 9. Sightings of Risso’s dolphins during 1993-98 aerial surveys. Contours in fathoms.

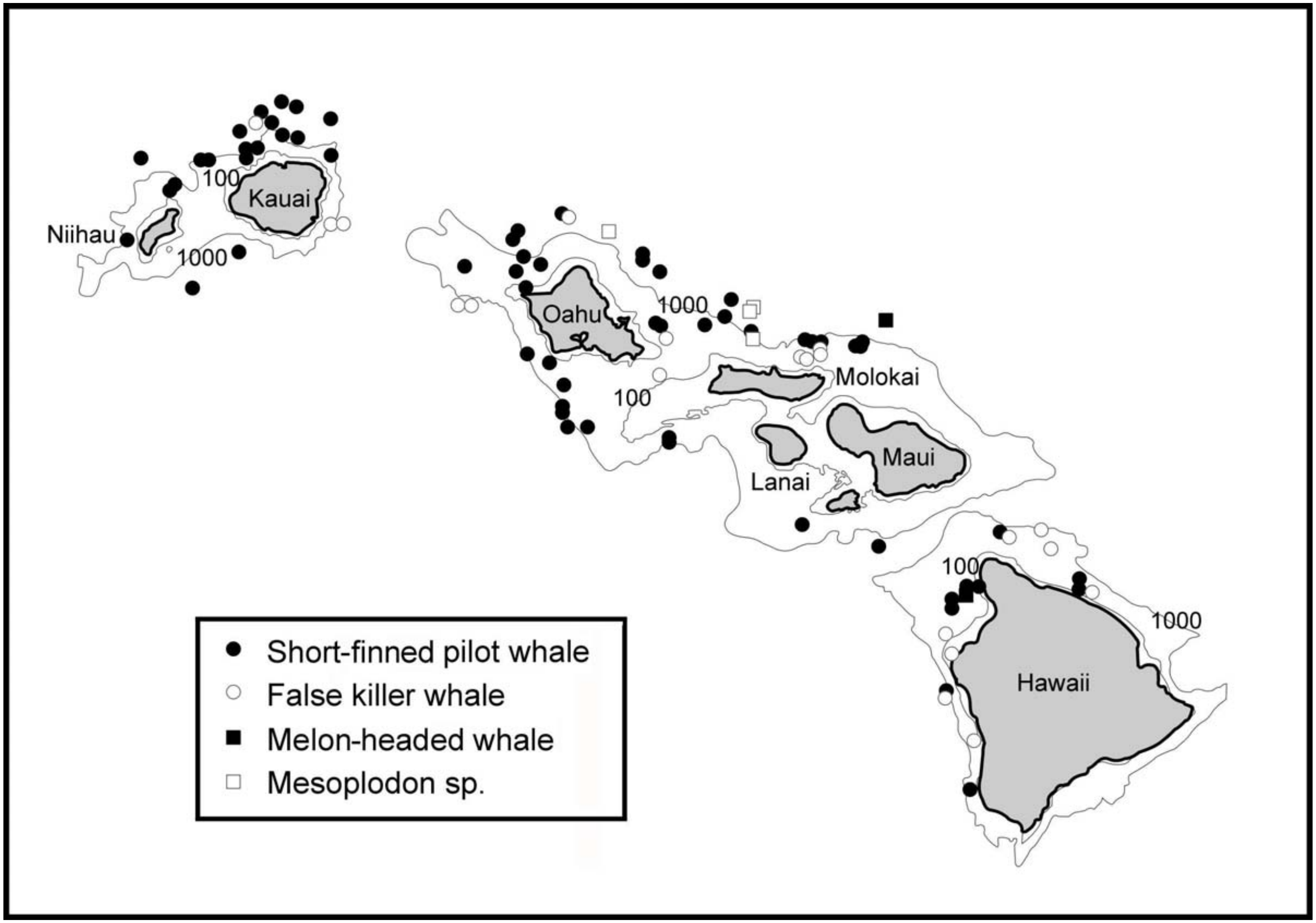

Figure 10. Sightings of short-finned pilot whales, false killer whales, melon-headed whales, and *Mesoplodon* beaked whales during 1993-98 aerial surveys. Contours in fathoms.

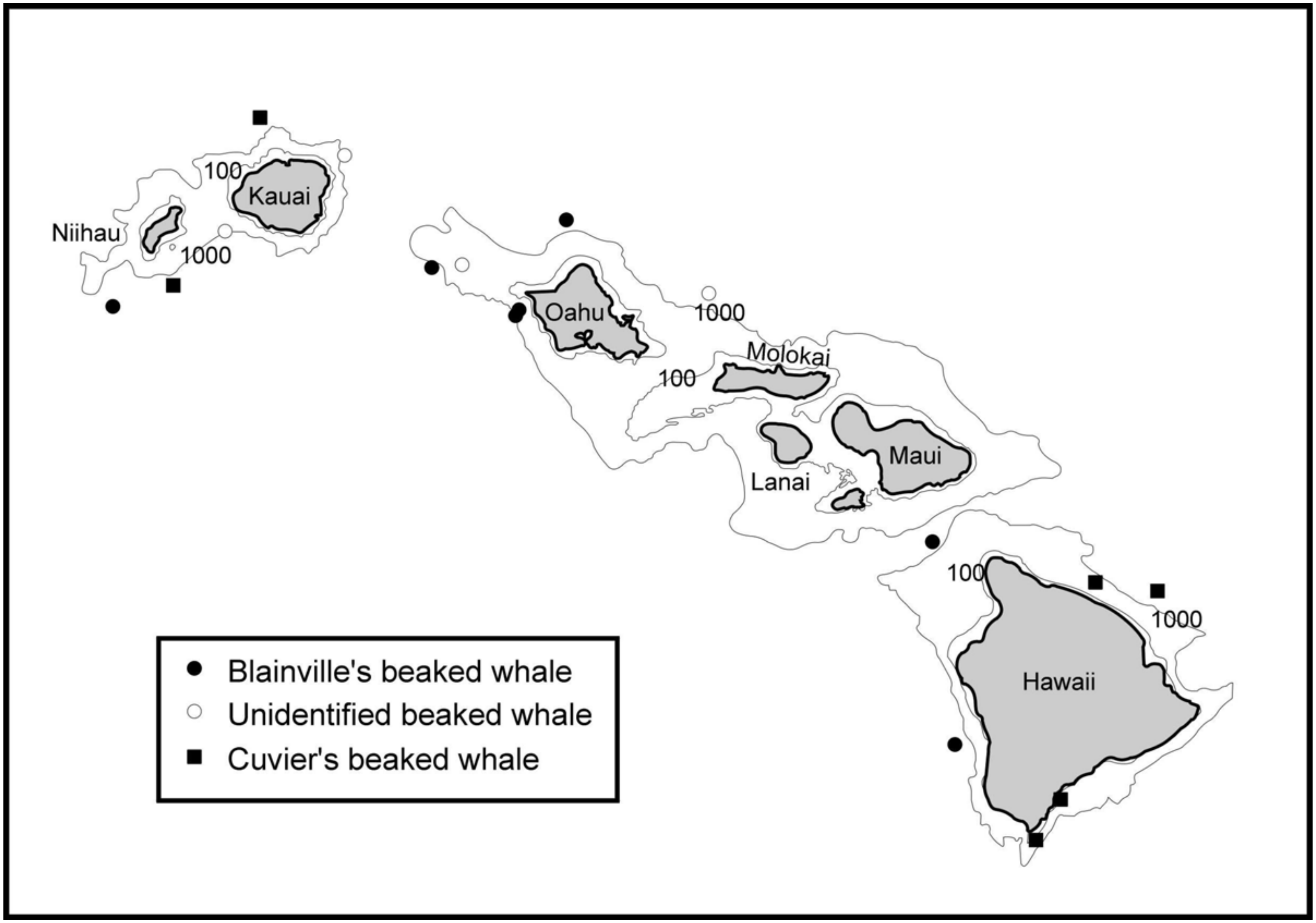

Figure 11. Sightings of Blainville’s beaked whales, Cuvier’s beaked whales, and unidentified beaked whales during 1993-98 aerial surveys. Contours in fathoms.

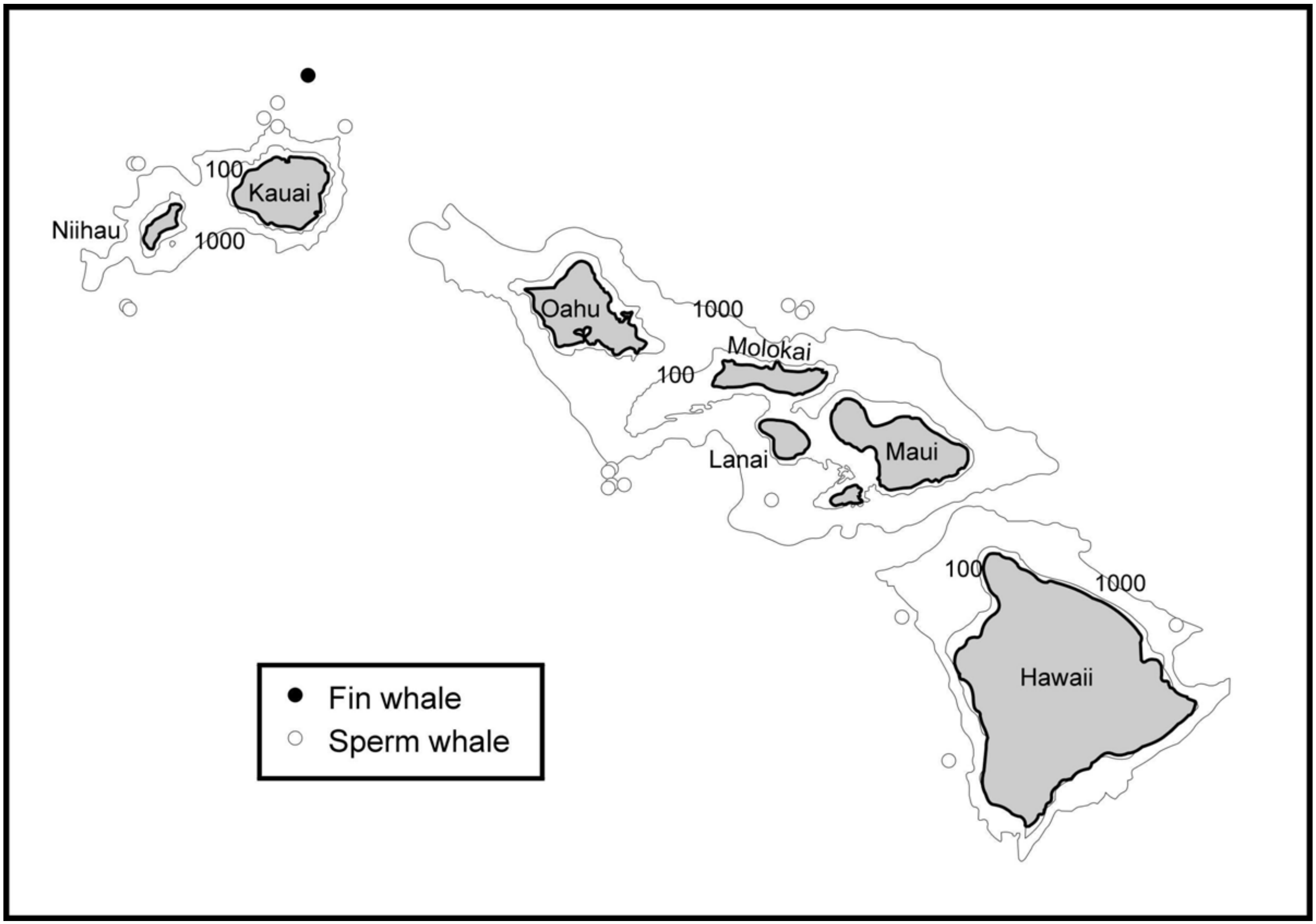

Figure 12. Sightings of sperm whales and fin whales during 1993-98 aerial surveys. Contours in fathoms.

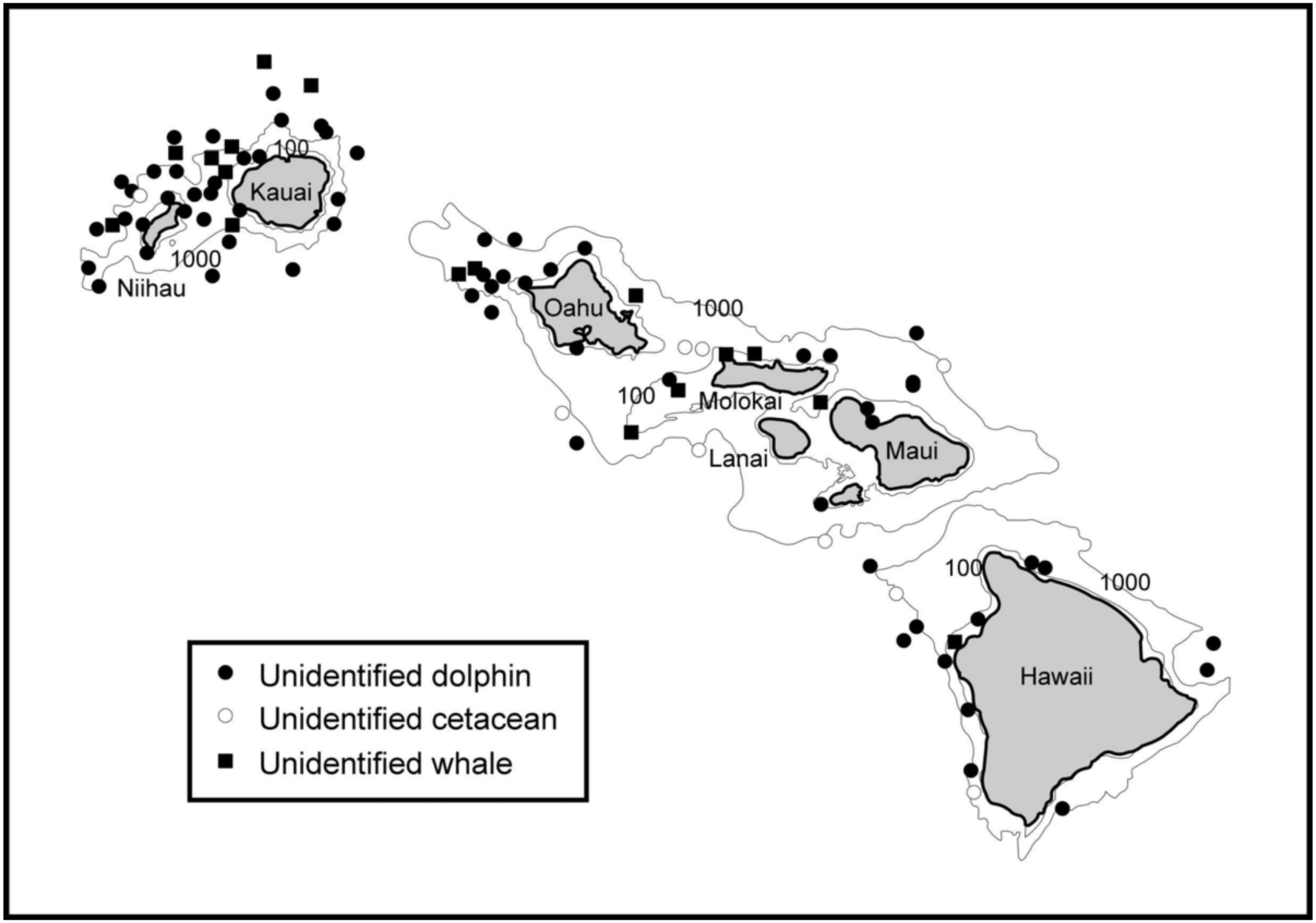

Figure 13. Sightings of unidentified dolphins, unidentified cetaceans and unidentified whales during 1993-98 aerial surveys. Contours in fathoms.

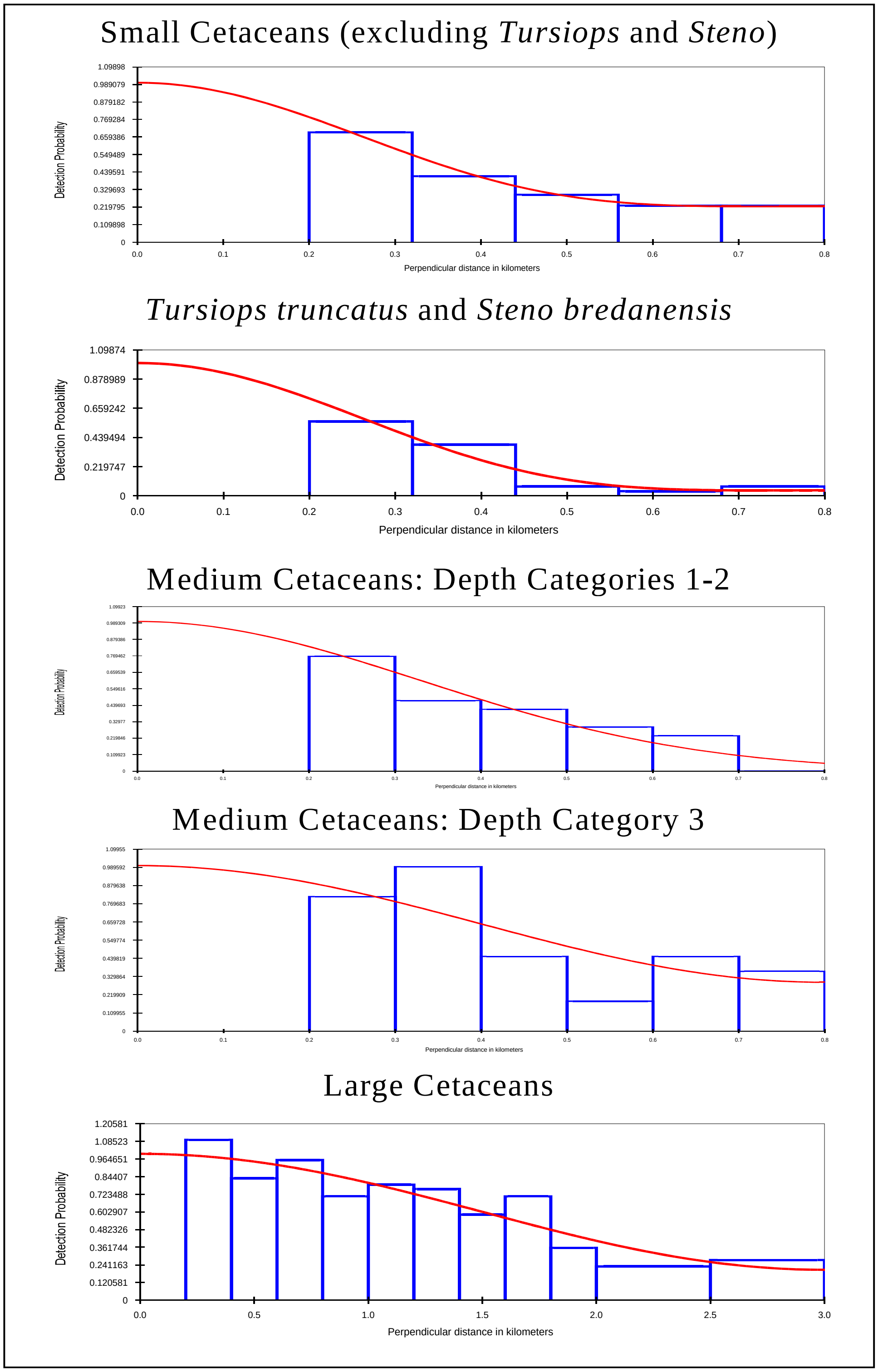

Figure 14. Histograms of perpendicular distances and fitted probability density functions for each of the five species groups. Left truncation distance was 0.2 km for all analyses; right truncation distances were 2.0 km for large whales and 0.8 km for all other groups.

APPENDIX

Guide to species and environmental codes used during 1993-98 surveys.

Codes for 1994 Humpback Whale Aerial Surveys by Rich Grotefendt revised 7/17/94

Beaufort Scale	Sea Condition	Wave Height	Wind Speed	Wind Description
0	Smooth and mirrorlike	0	0-1	calm
1	Scale-like ripples without foam crest	1	1-3	light air
2	Small short wavelets; crests glass appearance and not breaking	2	4-6	light breeze
3	Large wavelets; some crests break; foam of glassy appearance; occasional white foam crests	3	7-10	gentle breeze
4	Small waves become longer; fairly frequent white foam crests.	4	11-16	moderate breeze
5	Moderate waves more pronounced long form; many white foam crests; there may be some spray	6	17-21	fresh breeze
6	Large waves form; white foam crests extensive; may be spray	10	22-27	strong breeze
7	Sea heaves; white foam from breaking waves blown in streaks in direction of wind; spin drift	14	28-33	mere gale
8	Moderately high waves of greater lengths; edges of crests break into spin drifts; foam blown in well marked streaks.	18	34-40	gale

EX Excellent (calm, clear, no glare)
VG Very good (some glare, surface ripple)
GO Good (light chop, glare, fog which makes viewing of less than 1/2 the survey strip troublesome)
FA Fair (chop, glare, shadows, fog, dirty ice, heavy rifting combine to make viewing of whole strip troublesome BUT all animals within line of sight are still visible)
PO Poor (some animals in survey strip are obscured due to weather conditions; survey data good for distribution analysis only)
UN Unacceptable (survey tract obscured; survey suspended)

Glare or Cloud Cover		VIS	BEAUF	GLARE
		(Acceptable Ranges for given VIS)		
blank if none		EX	0-1	blank
1 = 1-10%	VG	VG	0-2	0-1
2 = 11-25%	GO	GO	0-4	0-3
3 = 26-50%	GO	FA	0-5	0-4
4 = 51-75%	FA	PO	0-5	0-4
5 = 76-100%	UN	UN	0-8	0-5
X = stopped before end of leg				

Species code
MN = Humpback whale — Megaptera novaeangliae
BP = Fin whale — Balaenoptera physalus
TG = Bottlenose dolphin — Tursiops truncatus
PM = Sperm whale — Physeter macrocephalus
GM = Shortfin pilot whale — Globicephala macrorhynchus
PC = False killer whale — Pseudorca crassidens
SL = Spinner dolphins — Stenella longirostris
SA = Spotted dolphin — Stenella attenuata
SC = Striped dolphin — Stenella coeruleoalba
FA = Pygmy killer whale — Feresa attenuata
PE = Mellon headed whale — Peponocephala electra
KB = Pygmy sperm whale — Kogia breviceps
BE = Baird's beaked — Berardius bairdii
MD = Blainville's beaked — Mesoplodon densirostris
ZX = Cuvier's beaked — Ziphius cavirostris
SB = Rough toothed dolphin — Steno bredanensis
MK = Monk seal — Monachus schauinslandi
ST = Stenella species
SS = Stenella species
UW = unidentified whale
UD = unidentified dolphin
UT = unidentified turtle
UB = unidentified beaked whale

Reaction N=None: no overt change in the direction of movement or behavior of an animal.
C=Change: overt change in the direction of movement or behavior of an animal.
E=Escape dive: dive associated with a splash or display of tail flukes.

Observer Codes
1=JM; 2=MS; 3=TN; 4=AF; 5=EB; 6=DW ; 7=KM ; 8= ; 9=RG

Position
1=left front; 2=right front (recorder) ; 3=left aft; 4=right aft.

Number
Total number of animals of the same species in a group, where a group includes all animals within four body lengths of one another.

Angle
Clinometer degrees (use the left scale on the clinometer) taken from platform to sighting on a line perpendicular to platform's direction of travel.

Altitude
Height of platform in feet.

Time Hours:Minutes:Seconds
Latitude Degrees:Minutes:Tenths of minutes (computer records hundredths mins)
Longitude same as latitude

Leg Number
Systematic legs are given a preassigned number. Deadheads start with one (1) each day and increment each time a deadhead is started. Randoms start with one (1) for the day and maintain the same number even when broken by a deadhead if the same flight path is resumed after the deadhead is concluded. Randoms increment when interrupted by a systematic or when the flight path has changed direction.

LEG TYPE
D Deadhead: For recording sighting data during reduced or undescribed observer effort. Also used on overland flights, commutes when not observing, during unacceptable weather conditions,...
S Systematic Straight flight of undefined length with beginning and ending positions systematically chosen. Observers on full effort.
R Random Straight flight path of underfined length with beginning and ending positions randomly chosen. Observers on full effort. On humpback 1994 study will also be lines connecting north-south systematic lines with observers on full effort. Will need to discuss modifications due to overlap.

LEG FLAG
1 = beginning of leg
2 = ending of leg
(note: At the end of each leg a duplicate line is written. The first line is a 2 and the next line is a 1. e.g 3S2
2D1

Wind speed Enter in knots.
Wind direction Enter in 0 to 360 degrees true.

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