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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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Inferring Trackline Detection Probabilities from Differences in Apparent Densities of Beaked Whales and Dwarf & Pygmy Sperm Whales in Different Survey Conditions

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Abstract

Visual line-transect surveys are commonly used to estimate the abundance of cetaceans (whales, dolphins, and porpoises). A key parameter in this method is the probability of detecting a cetacean that is directly on the transect line or *g(0)*. Beaked whales and dwarf & pygmy sperm whales are visually inconspicuous and dive for long periods of time. Previous studies have shown that trackline detection probability is low for these species even in the best survey conditions. Trackline detection probability has never been estimated for them in poor survey conditions. A method is developed here to estimate the relative values of trackline detection probability by comparing estimates of apparent density in different survey conditions (measured as Beaufort state) using estimated density in the best survey conditions as a reference point. Using data from line-transect surveys in the eastern tropical Pacific, this approach yields consistent estimates of trackline detection probability for beaked whales and for dwarf & pygmy sperm whales as functions of sighting conditions in two adjacent study areas. Results show that *g(0)* for beaked whales is similar for Beaufort 0 and 1 conditions but decreases with increasing Beaufort to less than 10% of that value in Beaufort 5. For dwarf & pygmy sperm whales *g(0)* decreases even faster with Beaufort state and, in Beaufort 2, is less than 10% of its value in Beaufort 0. These relative values of *g(0)* are used to extrapolate published estimates of *g(0)* for calm seas to yield values for Beaufort states 0 to 5.

Introduction

Line-transect methods are often used to estimate the density and abundance of cetacean species (whales, dolphins and porpoises) based on visual sighting surveys conducted from ships or aircraft. A defined study area is surveyed with systematic or random transect lines, and cetacean density is calculated using either conventional distance sampling or multiple-covariate distance sampling methods (Buckland *et al*. 2001; Buckland *et al*. 2004). One common assumption of both methods is that all animals directly on the transect line are seen or that the fraction of detected animals can be estimated (the trackline detection probability or *g(0)* in distance sampling terminology). Cetacean species are typically seen only when some portion of their body is above the water's surface or, for larger cetaceans, when their exhalations are visible as a distinct blow. Cetaceans are not visible when diving, which would result in an underestimate of density if corrections were not applied for missed animals. This is referred to as availability bias. An additional bias, perception bias, can occur if animals surface within the visual range of observers but are not seen. This can result because the visual observers were not looking in the right direction, because the surfacing was obscured by waves, or a wide variety of other factors. Perception bias is strongly affected by weather and other conditions that affect search effectiveness, especially for inconspicuous cetacean species. The concepts of perception and availability bias (as conceived by Marsh and Sinclair 1989) are helpful, but in reality the two can be convolved. Visual observers on ships typically search in a 180° arc in front of the survey vessel and out to the horizon. The probability of detecting a surfacing cetacean declines with its distance from the survey vessel, and there is no distance at which an animal suddenly becomes unavailable to being seen. At larger distances, the probability of detection becomes essentially zero, but that distance depends on sighting conditions. Consequently, availability also depends on sighting conditions. Laake and Borchers (2004) reviewed many methods that have been developed to estimate availability bias, perception bias, or the combined effect of both for line-transect surveys.

Perception bias is typically estimated using data from two independent sets of observers on the same survey vessel. The independent observers can use the same detection methods (such as visual observers stationed on different levels of a ship) or can use complementary methods such as visual and acoustic approaches to detecting animals. Mark-recapture methods are then used to estimate the probability of one or both sets of observers missing an animal or group. The probability of detecting a group can be either positively correlated for the two sets of observers (as is usually the case for two sets of visual observers) or negatively correlated (as may be the case for visual and acoustic detections of a species that does not vocalize at the surface). Many sophisticated statistical methods have been developed minimize to bias caused by these correlations (Borchers *et al*. 1998; Laake and Borchers 2004), but these methods cannot account for availability bias caused if an animal is not available to either observer.

The estimation of availability bias typically requires more than one opportunity to detect an animal. Hiby and Lovell (1998) developed a “loop-back” method for aerial surveys to estimate availability bias for harbor porpoise. Skaug and Schweder (1999) developed a method that uses information on surfacing rates and information from multiple surfacings recorded over a short period of time by a single set of observers to estimate availability bias. Other approaches to estimating availability bias use information on diving and surfacing behavior collected at other times with other methods (Barlow *et al.* 1988; Schweder *et al*. 1999)

Several methods have been used to simultaneously estimate perception and availability bias for cetacean line-transect surveys. An approach developed by Buckand and Turnock (1992) uses a “tracker” who can detect cetaceans at greater distance and visually track the animals as the ship approaches. This sets up an experimental trial for the main observers who either do or do not detect the tracked group. This latter approach also allows correction for bias caused by reactive movement of animals in response to the survey vessel. Laake *et al*. (1997) used observers on land and in aircraft to directly estimate trackline detection probability for harbor porpoise aerial surveys. Barlow (1999) used models of animal diving behavior, binocular search patterns and radial detections distances to estimate trackline detection probability for beaked whales (Ziphiidae) and dwarf & pygmy sperm whales (*Kogia* spp.). Two different detection methods (e.g. visual and passive acoustic methods) can be used from one platform to help quantify the fraction of animals missed by both methods and can thereby estimate elements of both availability and perception bias, but this approach has not been used to date for beaked whales or for dwarf & pygmy sperm whales.

Despite recent advances in methods to estimate availability bias, perception bias, and trackline detection probability for cetacean surveys, these quantities have not been estimated for most cetacean surveys, and available estimates often pertain to a narrow range of sighting conditions. For inconspicuous species like beaked whales and dwarf & pygmy sperm whales, trackline detection probabilities may be especially dependent on sighting conditions, but values for different sea states have typically not been estimated (Barlow 1999). Dual-platform methods are expensive to implement and require a separate independent team of observers, which is often logistically infeasible. For long-diving whales, it is not practical to use methods that require observations from multiple surfacings. Methods are needed that can be applied more generally to a wide variety of species to estimate trackline detection probabilities.

Here I present a new method to estimate trackline detection probabilities for small beaked whale species (*Ziphius cavirostris* & *Mesoplodon* spp.) and for dwarf & pygmy sperm whales based on the simple concept that true density does not change with sighting conditions. If density is estimated for a given study area in a variety of sighting conditions, the estimates made in the best conditions will be less biased than estimates made in poorer conditions. The degree to which estimates differ in differing survey conditions can be used to infer relative difference in trackline detection probabilities. If trackline detection is certain ($g(0)$ = 1.0) in the best survey conditions, absolute estimates of detection probability can be made for all other conditions from the ratio of density estimates. If some individuals are missed even in the best survey conditions, but trackline detection probabilities can be estimated for those conditions (e.g., Barlow 1999), this method allows extrapolation of those estimates to poorer survey conditions.

This method is applied to estimate relative values for trackline detection probability for a pooled category of small beaked whales (Cuvier’s beaked whale, Blaineville’s beaked whale – *Mesoplodon densirostris*, and pygmy beaked whale – *Mesoplodon peruvianus*) and a pooled category of pygmy and dwarf sperm whales (*Kogia breviceps* and *Kogia simus*, respectively). This method requires large sample sizes to statistically tease apart the effect of trackline detection probability from other factors that influence cetacean densities, such as geographical variation in density. I use a compilation of cetacean line-transect survey data collected by the Southwest Fisheries Science Center on 175,000 km of cetacean surveys conducted by ships from 1986 to 2008 in the eastern tropical Pacific Ocean (ETP).

Methods

Field Methods

Density of a variety of cetacean species is estimated from data collected by the Southwest Fisheries Science Center on dedicated cetacean survey cruises from 1986-2008. Line-transect methods were used on all these surveys with consistent survey methods throughout the time period (Kinzey *et al*. 2000). In brief, two experienced marine mammal observers searched with 25X pedestal-mounted binoculars from the flying bridge deck of 51-65 m research vessels. A third observer searched using unaided eyes and (occasionally) 7X binoculars and acted as data recorder. Survey conditions (Beaufort sea state, swell height and visibility) were recorded every 30-40 minutes or whenever conditions changed. When cetaceans were seen within 3 nmi of the transect line, the ship was maneuvered to approach the animals so that the observers could better determine the species present and estimate the group size. Vessels covered pre-determined transect lines that representatively sampled an explicit study area.

Trackline detection probabilities (*g(0)*) are estimated here for cryptic, hard-to-see species for which detection probabilities are expected to be extremely dependent on survey conditions, including Cuvier's beaked whale, Blaineville's beaked whale, pygmy beaked whale, dwarf sperm whale, and pygmy sperm whale. Here *g(0)* is estimated for a pooled category of all small beaked whales including the genera *Ziphius* and *Mesoplodon* and "unidentified beaked whales" (beaked whales which were identified as being either *Ziphius* or *Mesoplodon*, but which could not be identified to species). Also, *g(0)* is estimated for a pooled category of dwarf and pygmy sperm whale (which includes a sighting category of *Kogia* spp. that could not be identified to species). Larger beaked whales that typically have a conspicuous blow, including Baird's beaked whales (*Berardius bairdii*) and Longman's beaked whales (*Indopacetus pacificus*), are not included.

Analytical Methods

Assuming that the true density of whales does not vary with sighting conditions, the ratio of densities estimates for poorer survey conditions to those for good conditions provides an estimate of the proportional differences in *g(0)* values. If *g(0)* = 1.0 in excellent conditions, these relative estimates of *g(0)* are also absolute estimates. If *g(0)* < 1.0 in excellent conditions but can be estimated (e.g., Barlow 1999), absolute *g(0)* for other conditions can be estimated by scaling the relative estimates. Beaufort state is a subjective measure of wind speed as perceived by visual appraisal of the effect of wind on the water's surface and has frequently been used as a measure of sighting conditions on visual line-transect surveys for cetaceans. Previous analyses of cetacean survey data have shown a measurable effect of Beaufort state on mean perpendicular sighting distances (Barlow *et al*. 2001) and on effective strip widths (Barlow *et al*. 2011) for all species, so Beaufort state is used here as a general measure of sighting conditions.

The density of groups of whales (number of groups per square kilometer) is estimated using a conventional line-transect approach. The density of groups, D_i, within Beaufort state i is estimated as

$$D_i = \frac{n_i \cdot f_i(0)}{2 \cdot L_i \cdot g_i(0)} \quad .$$

where L_i = the length of "on-effort" transect lines in Beaufort state i,
$f_i(0)$ = the probability density of the detection function evaluated at zero perpendicular distance,
$g_i(0)$ = the trackline detection probability, and
n_i = the number of sightings of that species.

If the probability of detecting a group of whales is assumed to be certain on the transect line ($g_i(0)$ = 1.0), the apparent density $({}_aD)$ can be estimated as

$${}_aD_i = \frac{n_i \cdot f_i(0)}{2 \cdot L_i} \quad .$$

Estimates of apparent whale density (stratified by Beaufort) are made for two geographic strata within the ETP study area: a northern inshore stratum and a northern offshore stratum (a third, southern stratum did not include sufficient search effort in low sea states to be included). The boundaries of these strata were chosen to include regions with similar mean sea state values within a stratum (Fig. 1). Values of $f_i(0)$ for each sea state are estimated using a hazard-rate model (Buckland 1985) fit to pooled distributions of perpendicular sighting distances for both areas (Tables 2 & 3). To preserve a large sample size of sightings, perpendicular distance distributions were not truncated.

Relative values of $g(0)$ at different Beaufort states (i = 1 to 5) are estimated with respect to its value at Beaufort state zero (excellent sighting conditions) as the ratio of apparent densities

$${}_Rg_i(0) = \frac{{}_aD_i}{{}_aD_0} \quad .$$

Overall estimates of relative $g(0)$ are taken as an average of relative values for the two geographic strata.

The absolute estimates of $g_1(0)$ for Beaufort 1 (very good sighting conditions) were previously estimated by Barlow (1999) for Cuvier's beaked whale, *Mesoplodon* species, and *Kogia* species[1]. Absolute estimates of $g_i(0)$ for other Beaufort states (i = 0 and 2 to 5) are estimated using the relative values calculated as above times the published values for good survey conditions.

$$g_i(0) = g_1(0) \cdot {}_Rg_i(0) / {}_Rg_1(0) \quad .$$

[1] Actually, Barlow (1999) estimated values of g(0) for Beaufort states 0 to 2, pooled. These values are assumed here to represent the average for Beaufort 1, the mid-point of the sea states used in that study.

Results

The number of sightings of each species is given in Table 1 for both study areas. Cuvier's beaked whale is the most frequently identified species of beaked whale, but overall there were more sightings of *Mesoplodon* than any other genus. Sample sizes in most categories are small, which is why all small beaked whales were pooled for this analysis. The dwarf sperm whale was seen much more often than the pygmy sperm whale. The number of pooled sightings and lengths of transect lines surveyed are given in Tables 2 & 3 for each of six Beaufort states. The encounter rates (sightings per km, Tables 2 & 3) clearly decline with increasing sea states. In part, this is due to decreasing values of the effective strip width ($1/f(0)$) (Fig. 2). However, the apparent densities of whales also decreased with increasing sea states (Table 2 & 3; Fig. 3), which should not occur if the decreases in effective strip width with Beaufort state adequately compensated for the decrease in encounter rates.

Apparent densities are based on the assumption that $g(0)$ values are the same ($g(0) = 1.0$) for all sea states. If whale density is not actually related to Beaufort state, the decline in <u>apparent</u> density with increasing Beaufort state implies that $g(0)$ values are not the same for all Beaufort states. Decreasing values of $g(0)$ with Beaufort state are needed to yield densities estimates that are the same for all Beaufort states. Relative values of $g(0)$ needed to give constant estimates of density at different Beaufort states are given in Table 2 and are illustrated in Fig. 4.

Estimates of relative $g(0)$ for small beaked whales are very similar for both Beaufort 0 and 1 in both geographic areas (Fig. 4). In contrast, relative $g(0)$ values for dwarf & pygmy sperm whales decline dramatically from Beaufort 0 to Beaufort 1 (Fig. 4). Barlow (1999) estimated absolute values of $g(0)$ for good survey conditions that include both perception bias and availability bias (Table 4). Combining published estimates $g(0)$ for Beaufort 1 (Barlow 1999) with the relative estimates of $g(0)$ for different sea states results in new estimates of $g(0)$ for Beaufort 0 and 2-5 that include affects of both perception and availability bias (Table 4).

Discussion

The abundance of beaked whales and dwarf & pygmy sperm whales has always been a challenge to estimate. Typically, sample sizes are small because these species are commonly seen only when conditions are very good, and good survey conditions are rare. These whales dive for long periods and spend very little time at the surface (Barlow 1999). Prior to this analysis, estimates of the probability of detecting beaked whales on a transect line, $g(0)$, had only been estimated based on surveys conducted in very good conditions. The methods used here allow the extrapolation of prior estimates of $g(0)$ to sea conditions that are more common (see Moore and Barlow 2013 for application of these values to analysis of beaked whale abundance trends). In Southwest Fisheries Science Center surveys of the ETP Northern Offshore area, beaked whales were seen more often in rough conditions (Beaufort 3-5) than in calm conditions (Beaufort 0-2), despite the much higher encounter rate in calm conditions (Table 2). The reason for this is that calm conditions are rare and only 14% of survey effort was conducted in calm conditions.

The ability to make valid quantitative estimates of whale abundance in rough seas is important for assessing the abundance of these species in offshore areas where calm conditions are rare. The approach used here appears to give consistent estimates of relative *g(0)* in different sea states for two different study areas. The standard errors in relative *g(0)* values are not estimated here, but are likely to be large. These estimates are made in reference to densities in Beaufort state zero, which are based on very small sample sizes. Given that Beaufort 0 and 1 result in very similar estimates of apparent density for beaked whales, a better approach might be to pool data from Beaufort 0 and 1 and to estimate relative *g(0)* values relative to densities in this pooled Beaufort category. However, estimates of relative *g(0)* for dwarf & pygmy sperm whales are quite different for Beaufort states 0 and 1. Alternatively, a regression-based method is proposed below which will allow estimation of relative *g(0)* values without reference to a single estimate of apparent density for "very good" conditions and which should therefore provide more statistically robust estimates.

The primary assumption of the method used here is that differences in apparent density estimated for different Beaufort states reflect differences in *g(0)* and not real differences in density. If whales were associated with persistently calmer or rougher areas, this approach would be invalid. In general, beaked whales are found in deep offshore waters that are less protected from rough weather than coastal waters, which would yield results opposite to those observed if this bias were strong. The two study areas chosen for this study have roughly even distributions of average sea states within them, so the observed pattern is not likely due to the coincidental occurrence of higher beaked whale densities in areas with calm weather. Also, both areas showed the same pattern of changes in apparent density with Beaufort state. In general, estimates from this approach will be valid either if real beaked whale density is uncorrelated with Beaufort state or if the study area is stratified to yield geographic strata with relatively uniform distributions of Beaufort state, as was done here.

The approach presented here for estimating relative *g(0)* values is likely to have little utility for single surveys of limited duration and sample size. The results presented here were possible only by pooling many surveys over many years. This general pattern of decreasing *g(0)* values with increasing Beaufort state would be expected for any survey, and an even greater rate of decrease might be expected for surveys from smaller survey vessels where observers are closer to the water surface.

As discussed above, the method presented here is imperfect and can be improved. The greatest problems with the approach are 1) relative *g(0)* values are estimated relative to densities in the best survey conditions for which sample sizes are small, and 2) relative *g(0)* values are based on comparison of apparent densities only within one category of Beaufort state without reference to the values of adjacent Beaufort levels. These shortcomings could be avoided with a regression-based approach that would fit a model of apparent density as a function of Beaufort state. Other measures of sighting condition, such as swell height, could also be added in a regression-based approach. Effective strip widths and *f(0)* values have already been estimated for a wide range of species and survey conditions (Barlow *et al*. 2011) and could be used in developing a density model. This model could be extrapolated to estimate density in the best survey conditions (e.g., Beaufort zero and no swell). Density in other survey conditions could be divided by this best-condition density to estimate relative *g(0)* values. Such a model could be extended via spatial modeling (Hedley *et al*. 1999) to include geographic differences in density, which would alleviate the need to stratify samples into regions with similar sighting conditions.

This paper is essentially a proof-of-concept. Differences in apparent density (estimated without *g(0)*) can be used to estimate relative values of *g(0)* in different survey conditions. Additional research is needed to refine this approach and to provide robust estimates of statistical uncertainty. A regression-based approach, possibly with generalized additive models (GAMs), may prove useful in this context.

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Table 1. Species of small beaked whales seen during surveys in the northern inshore and offshore strata of the eastern tropical Pacific study area. Species include two categories that could not be identified to species. Sightings that were identified in the field as *Mesopodon* spp.*A* (an unnamed species of beaked whale) are assumed to be *M. peruvianus* adult males (Pitman and Lynn 2001).

Species	Northern Inshore Stratum	Northern Offshore Stratum	Pooled Study Areas
Mesoplodon peruvianus – pygmy beaked whale	45	3	48
M. densirostris – Blaineville's beaked whale	1	2	3
Ziphius cavirostris – Cuvier's beaked whale	94	14	108
Unid. small ziphiid	119	26	145
Unid. *Mesoplodon* spp.	94	12	106
Kogia simus – dwarf sperm whale	150	22	172
Kogia breviceps – pygmy sperm whale	10	0	10
Unid. *Kogia* spp.	15	3	18

Table 2. Line transect estimates of the apparent density of small beaked whales in two regions within the ETP study area. Apparent densities assume that *g(0)* = 1.0. Also included are the number of sightings (*n*), the lengths of transect lines (*L*), the encounter rates of groups (groups km^{-1}), *f(0)*, and effective strip widths, all stratified by Beaufort state.

Region	Beauf. State	*n*	*L* km	Encounter Rate km^{-1}	*f(0)* km^{-1}	*ESW* km	Group Density	Relative *g(0)*
ETP Northern Inshore Stratum								
	0	15	1245	0.0121	0.279	3.58	0.0017	1.000
	1	90	8675	0.0104	0.327	3.06	0.0017	1.007
	2	119	22338	0.0053	0.393	2.54	0.0010	0.617
	3	81	35917	0.0023	0.633	1.58	0.0007	0.431
	4	43	38990	0.0011	0.692	1.45	0.0004	0.225
	5	5	15243	0.0003	0.834	1.20	0.0001	0.074
ETP Northern Offshore Stratum								
	0	1	154	0.0065	0.279	3.58	0.0009	1.000
	1	9	1622	0.0055	0.327	3.06	0.0009	0.992
	2	17	5448	0.0031	0.393	2.54	0.0006	0.672
	3	17	10987	0.0015	0.633	1.58	0.0005	0.524
	4	9	21156	0.0004	0.692	1.45	0.0001	0.153
	5	4	12753	0.0003	0.834	1.20	0.0001	0.138

Table 3. Line transect estimates of the apparent density of dwarf and pygmy sperm whales (*Kogia* spp.) in two regions within the ETP study area. Apparent densities assume that *g(0)* = 1.0. Also included are the number of sightings (*n*), the lengths of transect lines (*L*), the encounter rates of groups (groups km^{-1}), *f(0)*, and effective strip widths (*ESW*), all stratified by Beaufort state. *ESW* and *f(0)* is not estimated for Beaufort 4 & 5 conditions due to a lack of sightings.

Region	Beauf. State	*n*	*L* km	Encounter Rate km^{-1}	*f(0)* km^{-1}	*ESW* km	Group Density	Relative *g(0)*
ETP Northern Inshore Stratum								
	0	26	1245	0.0209	0.481	2.08	0.0050	1.000
	1	87	8675	0.0100	0.451	2.22	0.0023	0.450
	2	48	22338	0.0021	0.459	2.18	0.0005	0.098
	3	12	35917	0.0003	0.734	1.36	0.0001	0.024
	4	0	38990	0.0000	n/a	n/a	0.0000	0.000
	5	0	15243	0.0000	n/a	n/a	0.0000	0.000
ETP Northern Offshore Stratum								
	0	3	154	0.0195	0.481	2.08	0.0047	1.000
	1	12	1622	0.0074	0.451	2.22	0.0017	0.356
	2	6	5448	0.0011	0.459	2.18	0.0003	0.054
	3	4	10987	0.0004	0.734	1.36	0.0001	0.029
	4	0	21156	0.0000	n/a	n/a	0.0000	0.000
	5	0	12753	0.0000	n/a	n/a	0.0000	0.000

Table 4. Published estimates of *g(0)* for *Mesoplodon*, *Ziphius* and *Kogia* (from Barlow 1999), relative values of *g(0)* for a pooled categories of small beaked whales and *Kogia* spp. (averages from Table 2), and new estimates of *g(0)* based on a multiplicative adjustment to published estimates for Beaufort 1 using relative values from this study. Published estimates are based on data collected in Beaufort states 0 to 2 and are assumed to represent an average for Beaufort state 1.

Genus/Species	Beaufort State	Published Estimates *g(0)*	Relative *g(0)*	New Estimates *g(0)*
Mesoplodon spp.				
	0		1.000	0.450
	1	0.45	1.000	0.450
	2		0.644	0.290
	3		0.477	0.215
	4		0.189	0.085
	5		0.106	0.048
Ziphius cavirostris				
	0		1.000	0.230
	1	0.23	1.000	0.230
	2		0.644	0.148
	3		0.477	0.110
	4		0.189	0.043
	5		0.106	0.024
Kogia spp.				
	0		1.000	0.868
	1	0.35	0.356	0.350
	2		0.054	0.066
	3		0.029	0.023
	4		0.000	0.000
	5		0.000	0.000

Figure 1. Eastern tropical Pacific (ETP) study area and smoothed contours of average Beaufort state. Beaufort states observed from transect lines during surveys were first gridded and then smoothed using a cubic spline. Geographic strata include the northern inshore and northern offshore areas, which show relatively uniform distributions of average Beaufort states within them. The southern area was not used due to an insufficient number of beaked whale sightings and a lack of surveys in Beaufort states 0 and 1.

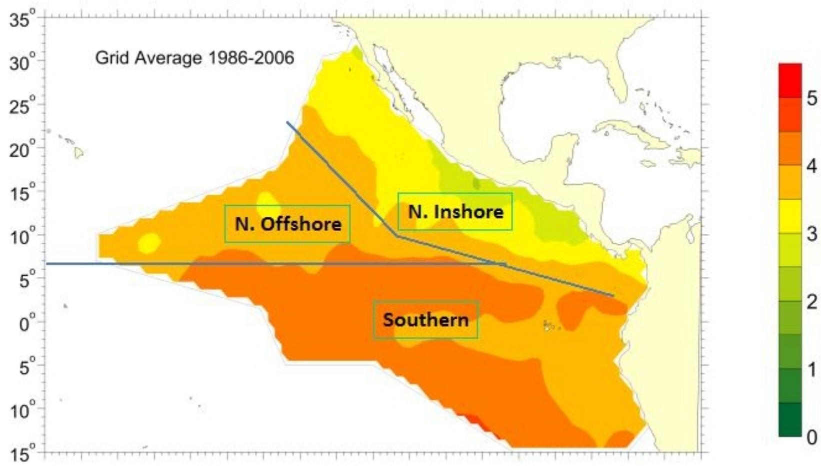


Figure 2. Estimated values of *f(0)* (red) and effective strip width (1 / *f(0)*) (blue) for small beaked whales in Beaufort states 0 to 5. A hazard-rate model is fit to observed distributions of perpendicular sighting distance without truncation for both geographic areas pooled.

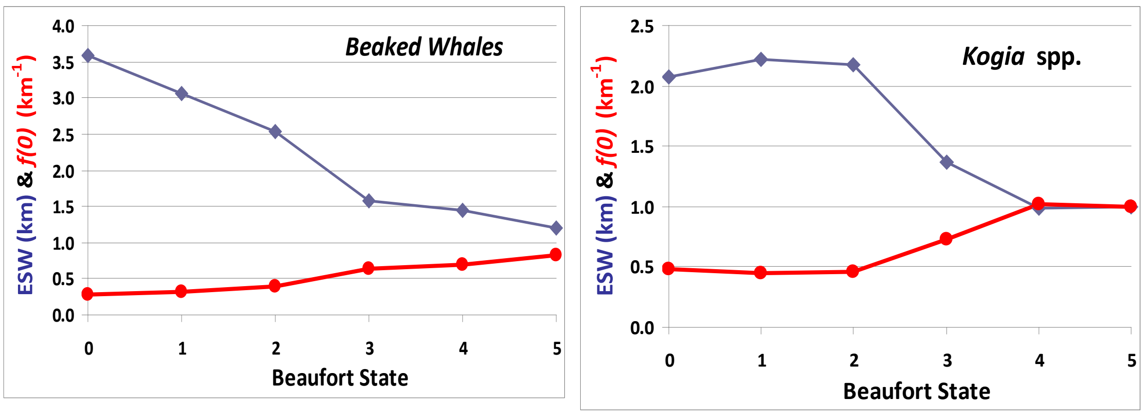


Figure 3. Apparent group densities of small beaked whales (left) and dwarf & pygmy sperm whales (right) in the ETP northern inshore (blue) and northern offshore (red) areas in Beaufort states 0 to 5. Apparent densities are estimated assuming that *g(0)* is 1.0.

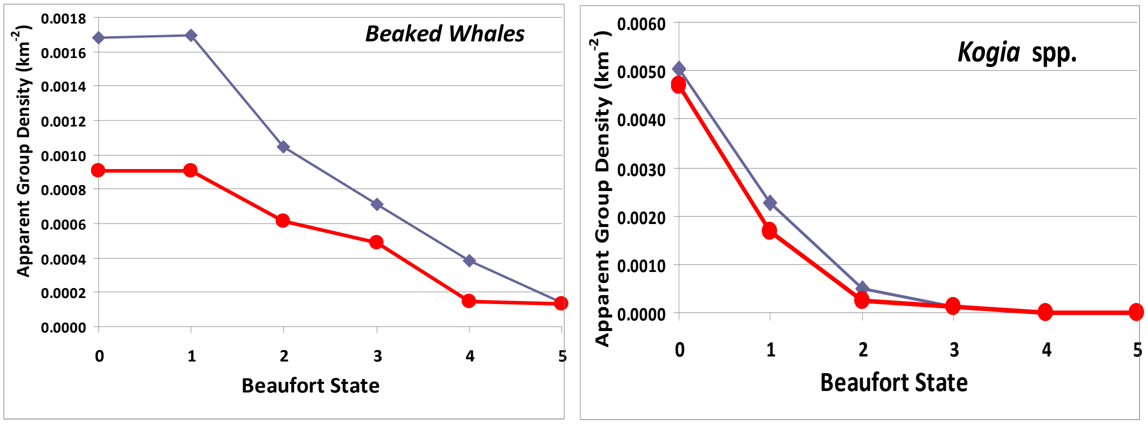
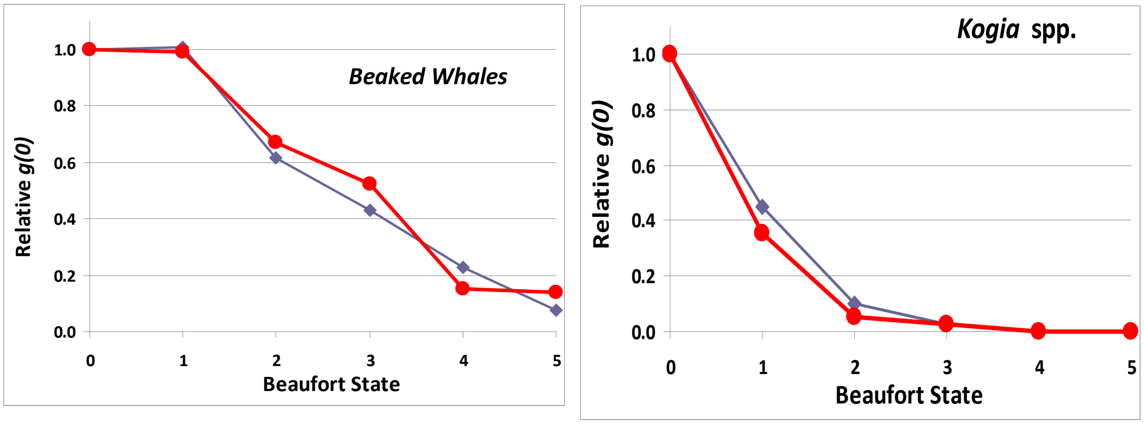


Figure 4. Relative values of *g(0)* for small beaked whales (left) and dwarf and pygmy sperm whales (right) inferred from differences in apparent density at different Beaufort states. The two lines represent the northern inshore (blue) and northern offshore (red) regions within the ETP study area.



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