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PROGRESS REPORT ON DEVELOPMENT OF AN INDEX OF RELATIVE ABUNDANCE FOR DOLPHINS FROM PURSE-SEINE OBSERVER DATA

Cleridy E. Lennert-Cody and Mark N. Maunder

1. BACKGROUND

Mortality of dolphins in the eastern Pacific Ocean (EPO) purse-seine tuna fishery is an iconic conservation issue. In the EPO, yellowfin tuna (*Thunnus albacares*) are often found in association with spotted (*Stenella attenuata*) and spinner (*S. longirostris*) dolphins (NRC 1992). Since the 1960s, purse-seine vessels have used this co-occurrence to locate the tuna by searching for dolphins, and associated birds, with high-power binoculars, and more recently, high-resolution radar and helicopters (NRC 1992; Lennert-Cody *et al*. 2001). Historically, this fishing method resulted in significant bycatch of dolphins, which has since been greatly reduced through the fishermen's ingenuity and implementation of management measures (MMPA 1972; Lo and Smith 1986; NRC 1992; Joseph 1994; Wade 1995; Hall 1998; IATTC 2013). Population dynamics modelling of dolphins in the EPO has historically been one of the primary means of evaluating the efficacy of bycatch reduction measures for these species (Gerrodette and Forcada 2005, Reilly *et al.* 2005, IATTC 2006; Wade *et al.* 2007, Gerrodette *et al.* 2008).

Dolphin population assessments require an index of either relative or absolute abundance from which inferences are made about trends in population size through time. Indices of dolphin abundance have been developed from both fishery-dependent and fishery-independent data. Indices of relative abundance were developed from purse-seine fisheries observer data in the 1980s based on line transect methodology (Buckland and Anganuzzi 1988; Anganuzzi and Buckland 1989; Buckland *et al*. 1992). During that period, binoculars were the primary method used by fishermen to locate dolphins and tuna. However, trend estimation was discontinued in 2000 due to concerns about changes in reporting rates of dolphin herd detections due to the increased use of helicopter and radar search (Lennert-Cody *et al*. 2001). Between 1979 and 2006, the US National Marine Fisheries Service (NMFS) conducted periodic fishery-independent surveys in the EPO for the purpose of estimating dolphin absolute abundance (Gerrodette *et al*. 2008, and references therein). While such surveys can have the advantage of avoiding time-varying biases due to changes in fishing behavior, they are costly and, as a result, obtaining adequate sample sizes for monitoring widely-distributed marine species is difficult.

Under the Antigua Convention, the Inter-American Tropical Tuna Commission (IATTC) has the responsibility to monitor the status of all species affected by the purse-seine fishery in the EPO, including dolphins (IATTC 2003). At present, as a result of a hiatus in fishery-independent surveys since 2006, purse-seine observer data are the only source of information with which to monitor EPO dolphin population status. This document presents preliminary results from the most recent attempt to estimate indices of relative abundance for EPO dolphins from those data.

2. DATA DESCRIPTION

2.1. General

During the course of daily fishing operations, IATTC observers aboard large[1] purse-seine vessels record data on vessel activities (*e.g*., running, searching, drifting, setting), fishing operations, and dolphin sightings. These data can be used to obtain estimates of distance and time spent searching, species and size composition of each dolphin herd sighted, and information on other factors that may affect dolphin herd sighting rates and herd size (*e.g*., fishing location, season, sighting method).

Large purse-seine vessels use several methods for searching for dolphins and tunas, some or all of which may be in operation when the vessel and crew are in active search mode. The three main search methods are binoculars (from one or several locations on the vessel), radar, and helicopter. Whenever the observer first becomes aware that the vessel crew has sighted a dolphin herd, he records the position of the vessel and the sighting method that reported the sighting. However, observers do not collect data on which search methods are actively in use during searching, nor on the position of the helicopter. Therefore, it is only possible to compute a general measure of searching effort from time and position data for the purse-seine vessel; it is not possible to allocate searching effort to each sighting method.

Dolphin sightings data may contain several estimates of herd size and species composition for each sighting, depending on whether or not the sighting led to a set. Observers record all dolphin sightings of which they are aware, but the accessibility of sighting information varies with the sighting method. An initial estimate of dolphin herd size and species composition is recorded by the observer as soon as he becomes aware of the sighting. This may be a crew member's initial estimate, or the observer's own initial estimate, if he is able to see the dolphins. If the dolphin herd is later involved in a set, the observer will continue to revise his estimate of herd size and species composition, producing a "best" estimate. Therefore, each dolphin herd sighting may have up to three estimates of herd size and species composition. Additional information recorded for each sighting includes: the distance and bearing to the sighting from the vessel, and the cue that led to the sighting (*e.g*., birds, dolphin splashes).

For this analysis, in an attempt to standardize searching practices among vessels and trips through time, data were limited by the following criteria:

1. To ensure homogeneity of searching techniques, data collected prior to 1990 were excluded,because information on radar use did not become available until the late 1980s (Lennert-Cody *et al*. 2001).
2. To ensure that vessel crew were actively searching for dolphins, trips making fewer than 5% of their sets on tunas associated with dolphins were excluded.
3. To ensure that the three main sighting methods (helicopter, radar, binoculars) were in use/operational at some point during each trip, thus increasing homogeneity of searching practices across trips and vessels, trips without at least one sighting by each of these three search techniques were excluded.
4. Days when the vessel was not actively searching with the observer on duty, days without at least two valid positions, days where the vessel was at or near full fish-carrying capacity (≥ 90% capacity), and days with rough sea state (Beaufort >4) (to exclude periods when detection might be impeded by weather) were excluded.
5. If one or more sets were made during a day, any recorded search and sightings between the sighting that led to a set and the set itself were excluded.

Further restrictions were applied to the dolphin sightings data. Sightings recorded as detected by "other" methods (most likely of observer-origin) were excluded, as were sightings with incomplete information (missing herd size, missing or unknown species composition). For the most part, these sightings were

[1] Defined as those with carrying capacities greater than 363 metric tons (IATTC Class 6), all of which are required to carry observers.

made by the helicopter too far from the vessel for any information on herd characteristics to be obtained. Sightings behind the vessel (bearing between 90°-270°) were also excluded; it is assumed that all searching effort is taking place in the direction of travel of the vessel.

Finally, in order to focus the present work on index development, the analysis was limited to the area of the EPO that defines the northeastern stock of the offshore spotted dolphin (north of 5°N and east of 120°W). Sightings for other dolphin species and stocks were not included in the present analysis, although they may be considered in the future.

2.2. Search effort

Search effort was computed in both distance, in kilometers, and time, in hours. Effort could only be computed for the vessel itself (not separately for each sighting method). A vessel was considered to be actively searching if the vessel was in active search mode (*i.e.*, not running, drifting, chasing or setting) and the observer was on duty. All events recorded by the observer during these active, on-duty search periods for each trip-day were processed to define searching 'segments.' A search segment was defined as any consecutive pair of events recorded by the observer. Search segment start and end positions were estimated if no positions were available (observers are not required to record positions for every type of event). Positions were estimated from known positions as close in time as possible to the segment without position information. Search segments were mostly short in duration; about 70% of were of less than one hour, and about 99% of less than 2 hours. If a search segment crossed 1°-area boundaries, effort and the corresponding sighting (if a sighting was made) were distributed between the 1°-areas, assuming a linear path between the segment start and end positions.

The spatial distribution of search effort within the northeastern offshore spotted dolphin area (Figure 1) is consistent with the general distribution of dolphin sets (*e.g.*, Watters 1999), and is similar to the spatial distribution of effort (in days fishing) used to compute the catch per unit of effort (CPUE) of yellowfin tuna by purse-seine vessels. Effort measured in kilometers was highly correlated with effort measured in hours (Spearman rank correlation coefficient = 0.95, $p < 0.01$) and therefore the analysis was based on search effort in kilometers.

2.3. Search behavior

Although the search effort associated with each of the three sighting methods (helicopter, radar, binoculars) is unknown, changes in the sighting reporting rates by the three methods suggest that searching techniques have evolved over the 1990-2012 period. The percentage of sightings by method has changed from mostly binocular sightings to mostly radar sightings (Figure 2). All three modes of searching show trends through time. Based on distance to reported sightings, the three different sighting methods appear to operate over different distance ranges from the vessel (Figure 3). However, sightings by all three methods were made close to the vessel, which is consistent with the reported use of helicopters to investigate radar sightings for the presence of tuna. The overlap in sighting distances means that sightings reported by binocular search may actually have been detected by the helicopter and/or on radar, but not reported.

The three sighting methods also differ in the percentage of sightings that led to sets (Figure 4). Helicopters had the highest percentage of sightings that led to sets, which is consistent with the ability of the helicopter crew to visually evaluate whether dolphin herds were associated with tunas. It is believed that helicopter crew only report sightings to the vessel that may be worth considering for a set. Dolphin herd size was nearly similar in non-set- and set-sightings reported by the helicopter and most different in non-set- and set-sightings reported by binoculars (Figure 5). The differences in sighting characteristics for helicopters and radar, as compared to binoculars, are likely indicative of an underreporting of sighting information by these two sighting methods.

In addition to long-term trends (Figures 2 and 4), the use of the different sighting methods, particularly the helicopter, appears to have varied from day to day within a trip, possibly as a function of the local availability of tuna. To illustrate this point, searching effort for a particular trip is shown in Figure 6. This trip illustrates that, even with the restrictions placed on data (see section 2.1), several modes of searching may occur during a trip: search that takes place during transit to a predetermined fishing area (characterized by mostly linear search movement through a larger area; 'transit' search), and search that takes place within a fishing area (characterized by multiple passes of the vessel through a relatively small region). In general, by trip, smaller areas with fewer kilometers of search had a slightly higher proportion of binocular sightings and lower proportion of helicopter sightings (Figure 7). One interpretation of this pattern is that helicopters are not as likely to be used during 'transit' search (*cf*. Figure 6). Although encounter rates (number of dolphin herds per kilometer searching) tended to be lower overall during portions of trips with limited search effort (Figure 8), the variability in encounter rates was also greatest for these low-effort trip sections. This pattern would be consistent with such sections being due to either transit search (lower encounter rates) or short periods of search within a productive fishing area (higher encounter rates). Therefore, it cannot be assumed that all trip-days with low search effort correspond to transit search. This implies that transit search needs to be inferred from 'local' search path characteristics (*e.g*., proportion of trip-days spent in a 2° or 5° area, or circular variance of 'local' search path).

3. DEVELOPMENT OF TRENDS MODEL

Given concerns raised previously about the suitability of these data for use with line transect methods (Lennert-Cody *et al*. 2001), as a first step, a CPUE-type approach to trend estimation was taken. The index of relative abundance was based on the number of animals per unit of search effort, in this case, number of dolphins per km searching per trip-day-1° area. A trip-day is the minimum time unit for the analysis because searching is a day-time activity, and it is not possible to unequivocally associate periods of search with individual sightings within a trip-day. Most trip-day-1° areas had no sightings, and few had more than three sightings (Figure 9). The counts of dolphins per herd tended to be right-skewed and exhibited a high degree of rounding (Figure 10).

To account for spatial effects on dolphin abundance, delta-lognormal generalized additive models (GAMs; Wood 2006; 2011) were fitted to the sightings and effort data. A logistic regression model was used to relate covariates to the probability of encountering one or more dolphins, and a lognormal model was used to relate covariates to the total number of dolphins seen. Because the lognormal model aggregates all dolphin herds seen during each trip-day-1° area, it does not allow for sighting-specific covariates (*e.g*., sighting method, non-set-sighting *versus* set-sighting, mixed- *versus* pure-species herd). Therefore, two different analyses were undertaken. The first analysis used only the data of sightings that led to sets because herd sizes of set-sightings were more similar across sighting methods than herd sizes of non-set-sightings (Figure 5). The second analysis used all sightings out to 20nm from the vessel for which there was an observer's estimate of herd size and species composition. The 20nm restriction had the greatest effect on helicopter sightings (Figure 3); almost all binocular sightings and most radar sightings were made within 20nm of the vessel. This data definition attempts to identify all the dolphin herds that would have been recorded as binocular sightings if they had not been recorded as sightings by the other methods. Excluded from both of these analyses were sightings for which there was only a crew initial estimate of herd size and species composition, both because crews do not distinguish between offshore spotted dolphins and coastal spotted dolphins, and because previous analyses (Buckland and Anganuzzi 1988) found differences in herd size estimates made by the observer and the crew for the same dolphin herd. Future plans to address the shortcomings of this approach are described in the Discussion section.

Two different approaches to trend estimation were taken. In the first approach, which produces a data-weighted index, one model was fitted to the full time period, and the index was obtained by the method of partial dependence (Hastie *et al*. 2009). The delta-lognormal GAM for this approach had the following two components:

$$\text{logit}(p) = \text{overall constant} + \text{year effect} + f_1(\text{month}) + f_2(1°\text{latitude}, 1°\text{longitude}) + f_3(\text{km})$$

$$\log(\text{CPUE}) = \text{overall constant} + \text{year effect} + f_4(\text{month}) + f_5(1° \text{ latitude}, 1° \text{ longitude})$$

where p = probability of seeing one or more dolphins; f_1 and f_4 are cyclic cubic spline smooth terms included to account for seasonal effects; f_2 and f_5 are two-dimensional smooth spatial surfaces (based on thin plate regression splines, with the maximum number of basis functions fixed at 70 for the logistic model and 30 for the lognormal model); f_3(km) refers to a smooth term for kilometers searched (based on thin plate regression splines); and CPUE refers to number of dolphins per kilometer per trip-day-1° area.

In the second approach, a simpler delta-lognormal GAM was fitted separately to the data of each year. This GAM had the following two components:

$$\text{logit}(p) = \text{overall constant} + f_2(1°\text{latitude}, 1°\text{longitude}) + f_3(\text{km})$$

$$\log(\text{CPUE}) = \text{overall constant} + f_5(1°\text{latitude}, 1°\text{longitude})$$

where variables and terms are as described above. The index of relative abundance was computed by predicting CPUE on the same fixed spatial grid for each year (based on the fitted GAM model of that year), and then summing the predicted CPUE over the cells of this spatial grid. The fixed spatial grid was the collection of 1° areas with any search effort in any of the 23 years. For prediction with the logistic component of this model, the value of the "km" term was fixed at the median kilometers searched per trip-day-1° area from the entire data set (42 km). This approach for estimating an index gives equal weighting to all cells of the fixed spatial grid. By contrast, in the first approach, areas with more effort in a given year will have more influence on the index value for that year. The number of trip-day-1° areas with effort and the number of sightings per year are shown in Table 1. All models were fitted with the *mgcv* library (Wood 2006) in *R* (R Core Development Team 2012).

4. RESULTS AND DISCUSSION

Both indices of relative abundance for the northeastern offshore spotted dolphin produced by fitting the above models to the effort and sightings data show an overall decreasing trend over the 1990-2012 period (Figure 11), with the data-weighted index showing a greater long-term decrease (Figure 12). Including sightings within 20nm of the vessel had little effect on the overall trends, as compared to the differences between the data-weighted and equal-weighted indices (Figures 11-12). The decreasing trend in the data-weighted index can be attributed to decreasing trends in the year effects for both the logistic and lognormal components (Figure 13). All model terms were highly significant (term-specific p-values were all << 0.01), which is not surprising given the number of observations (Table 1). However, simple model diagnostics (percent deviance explained, residual plots) suggested that the model fit to the data could be improved. For all models, the percent deviance explained by each component was 8-18%. The fit would be improved to some extent, particularly in the analysis of the full time period, by allowing for more wiggly surfaces and smooth terms; however, the point of constraining the wiggliness was to maintain somewhat similar model characteristics among years and between the two GAM approaches.

The level of agreement of these indices with published trends varies. There is close agreement between these delta-lognormal GAM-based indices and the 1990-2000 index of relative abundance based on line transect analysis of only vessels with both helicopter and radar onboard (Figure 14; Lennert-Cody *et al*. 2001). This level of agreement suggests that the different treatments of the data by the line transect and CPUE-type GAM approaches do not appear to markedly change the overall trend estimated from these data. For example, the GAMs disregard any effect of herd size on detection. Comparison of the delta-lognormal GAM indices to the NMFS survey estimates of abundance (Gerrodette *et al*. 2008) does not show good overall agreement. Although both sets of GAM indices and the NMFS survey estimates suggest lower abundance in the late 1990s compared to the late 1980s and the early 2000s, the survey estimate for 2006 does not show the decrease that is seen in the GAM indices.

At present, it remains unclear whether indices of relative abundance for dolphins computed from the purse-seine data can be used to reliably track dolphin abundance. It is believed that the purse-seine yellowfin tuna index computed for the stock assessments tracks yellowfin abundance because of similarities in the yellowfin indices computed for the purse-seine fishery and the longline fishery (Figure 15), keeping in mind that the two fisheries catch different sized (age) fish and the trend will be lagged accordingly. The delta-lognormal GAM indices for the northeastern spotted dolphin show a striking similarity to the indices of relative abundance for yellowfin tuna computed from purse-seine data (Figure 15). Given that percentage of sightings leading to sets has been fairly constant through time for each sighting method (Figure 4), the delta-lognormal GAM index may largely reflect fishermen's ability to locate areas where dolphins are associated with tunas, instead of indexing changes in the absolute abundance of dolphins. It is believed that fishermen always leave port with a fishing plan, based on their own previous experience and/or information from other fishermen. This plan may be modified at sea, depending on the current fishing conditions. Therefore, during periods when tuna abundance is high, dolphins everywhere may be associated with tunas and less effort will be expended to find areas with dolphin-associated fish. On the other hand, when tuna abundance is low, fishermen have to work harder to find areas where dolphins are associated with tunas, increasing effort and decreasing the index.

The searching effort used in the present analysis was selected to try to ensure that the vessel crew were actively searching for dolphins, and searching with similar methods on all vessel trips. However, other search effort might be considered in future analyses, such as that of vessels that do not make sets on tunas associated with dolphins. Similarly, other sighting data might also be considered, such as sightings of observer origin. These other data sources will have different biases, and it remains to be seen if the different data sources with their different biases can be reconciled in a useful manner. In addition, it may also be possible to extend the analyses back in time to cover the 1980s. However, the lack of information on radar use in the mid-1980s (Lennert-Cody *et al*. 2001) will make this task problematic. Finally, removing late-afternoon search, which may have a lower encounter rate due to the sundown prohibition (IATTC 2009 and references therein), may be useful with respect to obtaining more homogeneous searching conditions over the period from 1990 to present.

There are several obvious shortcomings of the delta-lognormal GAM models fitted to the dolphin data, and correcting them may improve the quality of the dolphin index computed from these data. First, the GAMs do not presently allow incorporation of sighting-specific covariates which affect herd size (Figure 5). A modification to occupancy-abundance mixture models (*e.g*. Sileshi *et al*. 2009) for the number of dolphins sighted per trip-day-1°, which will allow for sighting-specific covariates, is presently being developed. Second, to further homogenize searching practices across trips through time, as well as within trips, several other covariates are presently being developed. The first is an indicator of 'transit' versus 'area' search (*e.g*. Figure 6). The second is a trip-specific reporting rate indicator that will be included in the model to try to capture trends through time in reporting rates, as inferred trip-level percentages of sightings and set-sightings, by sighting method (*cf* Figures 2 and 4).

If the above-mentioned improvements show promise, several other modeling options may also be considered. For example, trends estimation may be explored with Bayesian mixing models (*e.g*. Moore and Semmens 2008; Erhardt and Bedrick 2013), which could allow for estimation of the relative mixture of searching by the various sighting methods. Also, issues related to herd size estimation might be considered, such as the problem of rounded counts of dolphins (Figure 10) and standardization of herd size estimates among observers. Finally, development of a species-level index for the offshore spotted dolphin and an index for the western-southern stock of offshore spotted dolphin will be considered.

5. CONCLUSIONS

Data collected by fisheries observers aboard purse-seine vessels in the EPO represent an extensive data resource, with historically better temporal and spatial coverage of the EPO than survey data. For these reasons, it would be advantageous to be able to use these observer data to develop an index of relative abundance for dolphins. However, as with all fishery-dependent data, the observer data do not represent random searching of the EPO, and the data may contain time-varying biases due to temporal changes in fishing behavior. Preliminary results obtained from the ongoing development of a CPUE-type dolphin index suggest that the non-random distribution of search effort may be problematic, resulting in a dolphin index that is very similar to the yellowfin tuna index. Further work to address this issue, as well as temporal changes in fishery operations, is being undertaken. At this point, it remains unclear whether indices of relative abundance for dolphins developed from the purse-seine observer data can be used to reliably track the absolute abundance of dolphin populations in the EPO.

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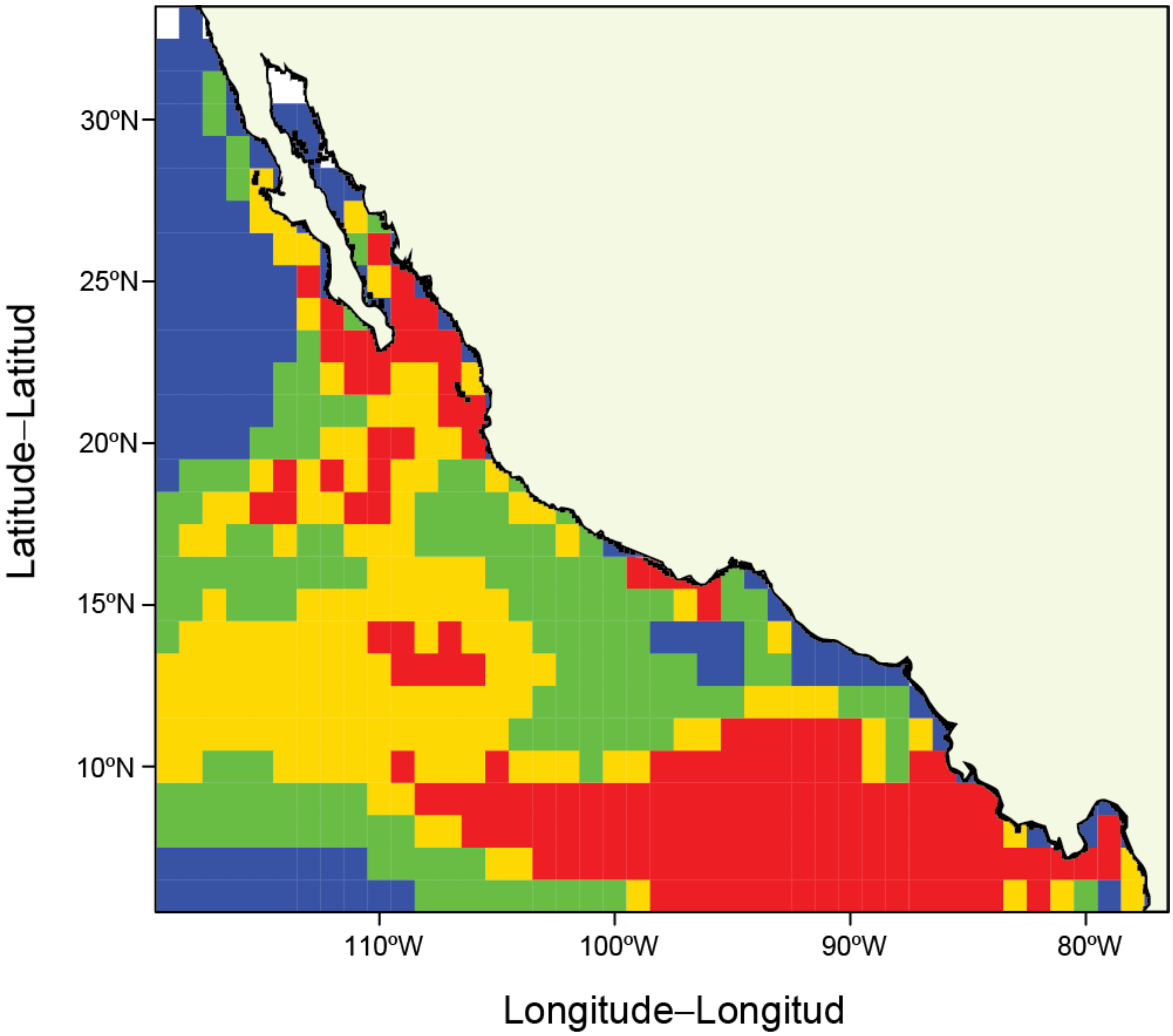

FIGURE 1. Map of kilometers searching by 1° area, 1990-2012, in the northeastern spotted dolphin area (north of 5° and east of 120°W). Blue: km ≤ 7300; green: 7300 < km ≤ 15300; gold: 15300 < km ≤ 23100; red: km > 23100.

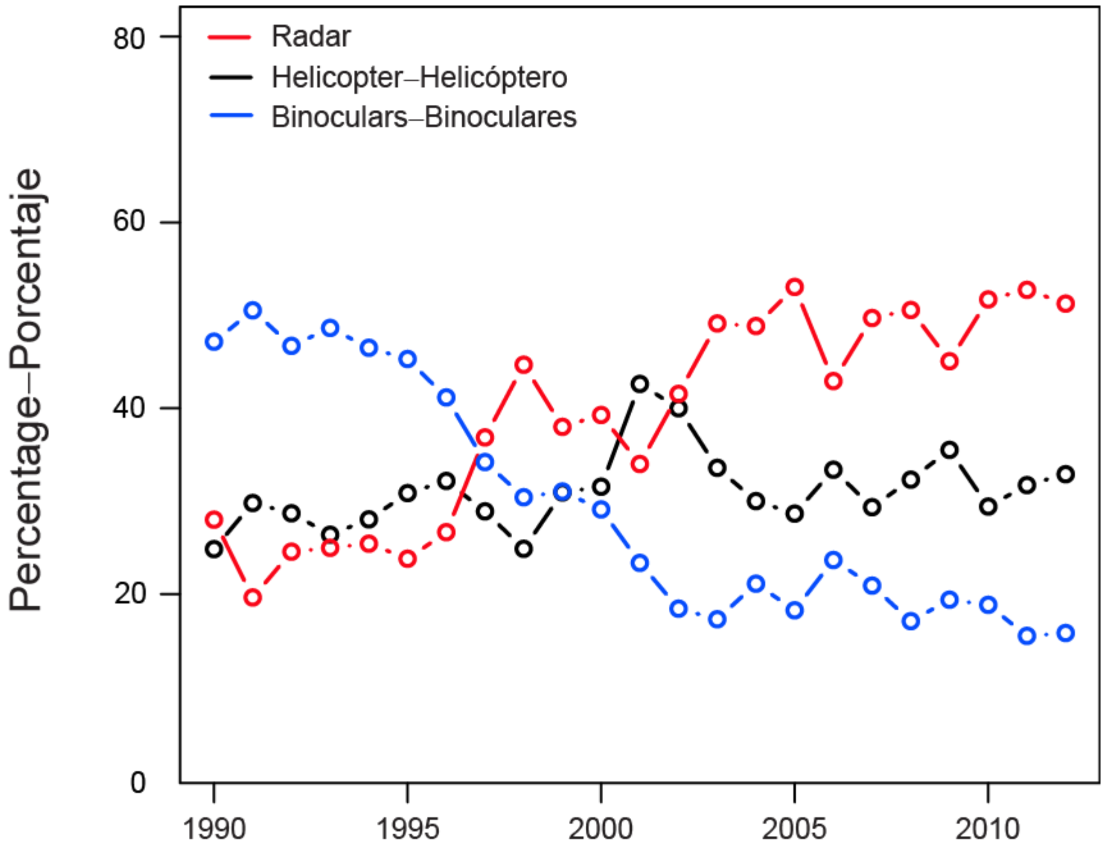

FIGURE 2. Percent sightings by sighting method and year, 1990-2013.

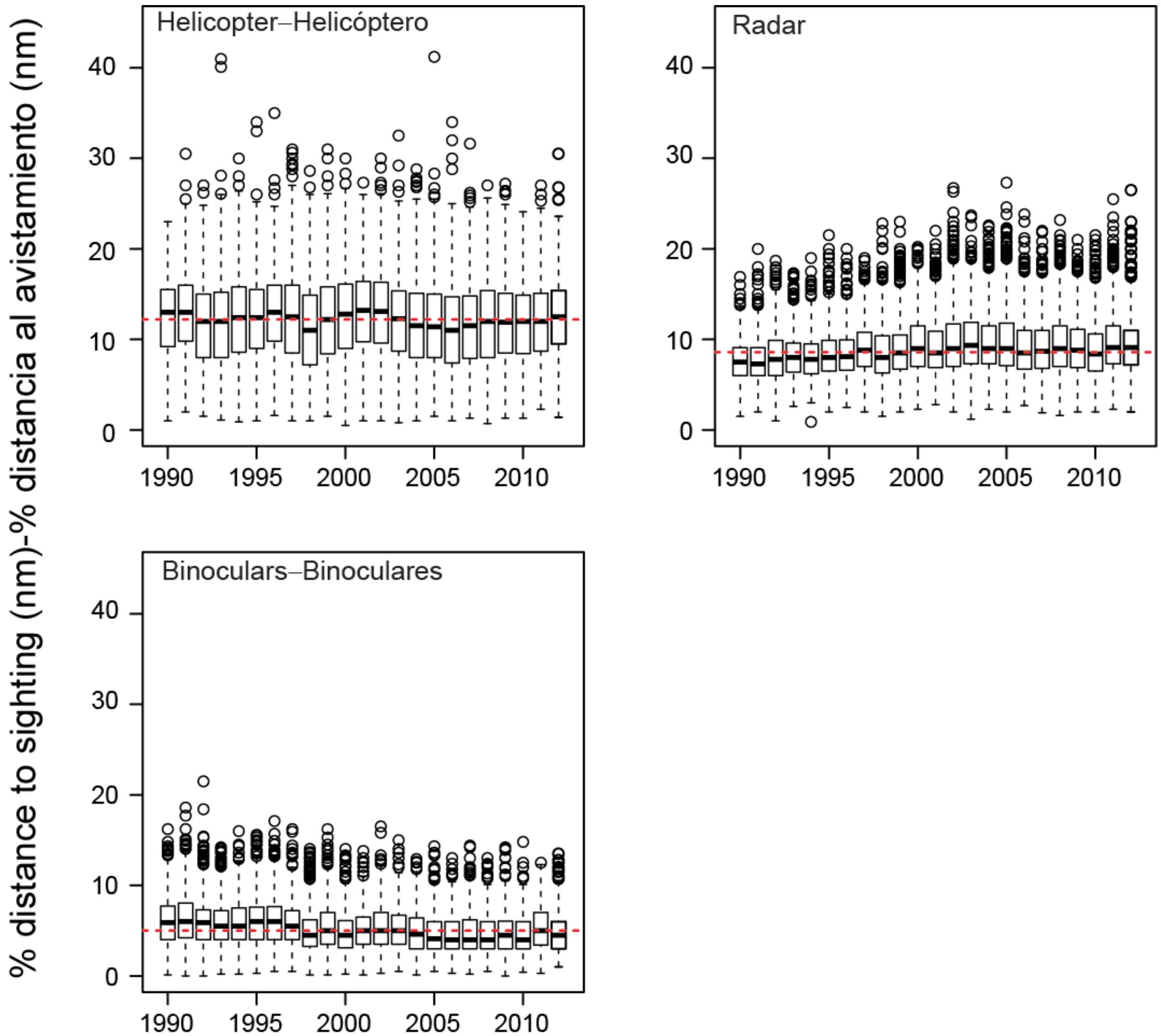

FIGURE 3. Box-and-whisker plots of distance to sighting (nm) from the vessel, by sighting method and year, 1990-2013. The red dashed line indicates the overall median distance.

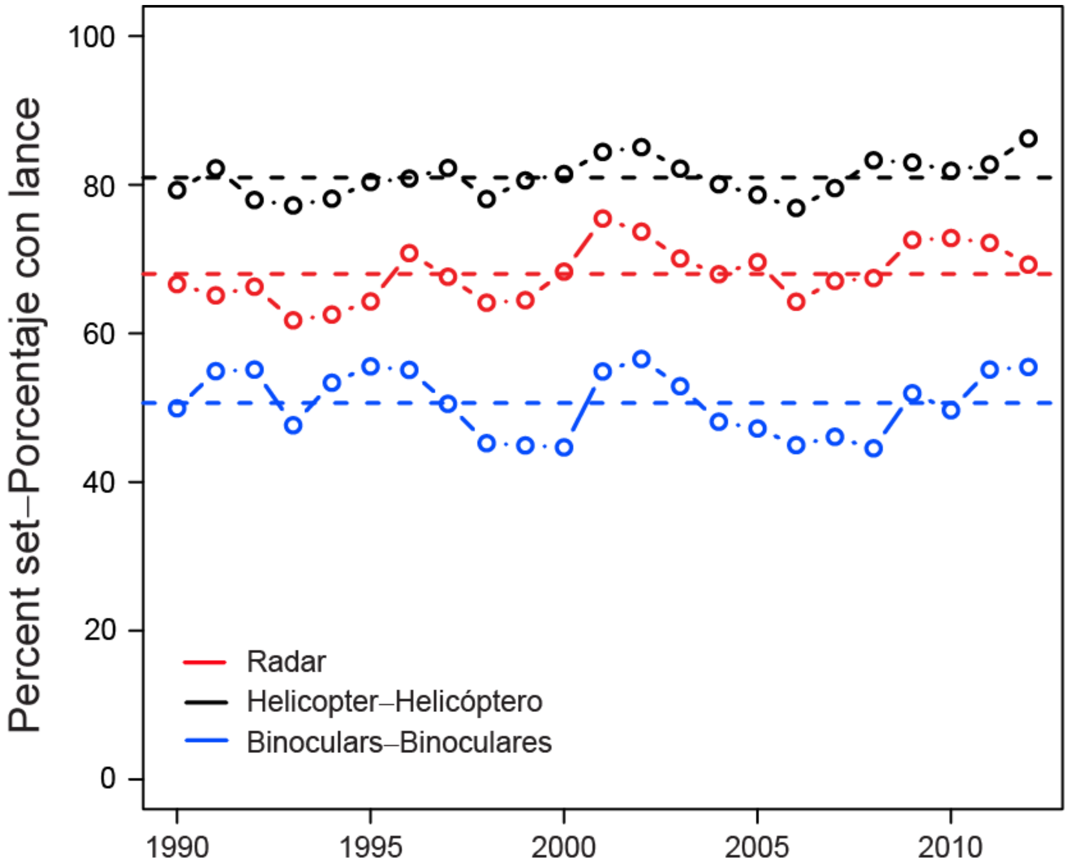

FIGURE 4. Percent sightings that led to sets, by sighting method and year, 1990-2013.

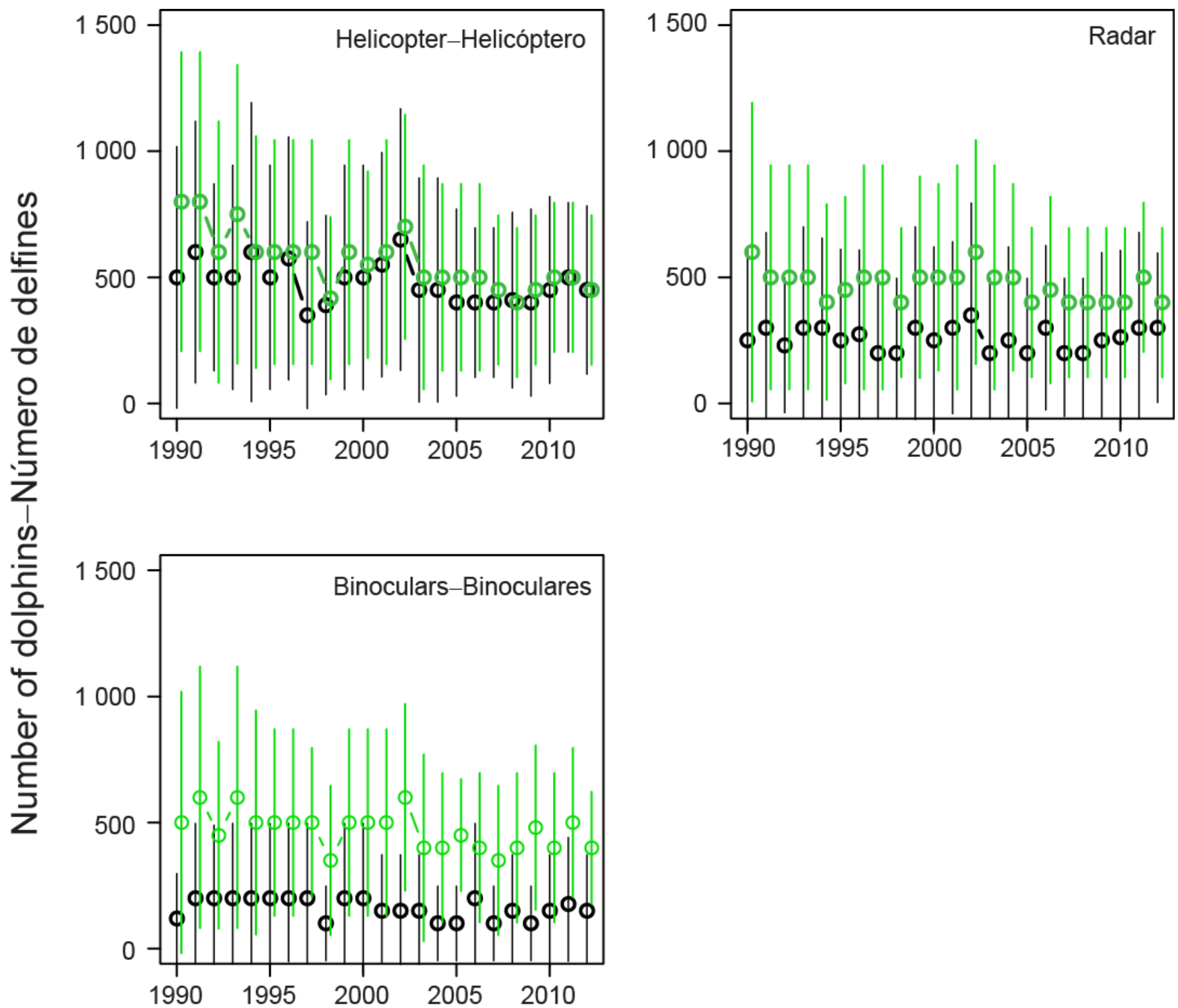

FIGURE 5. Median number of dolphins per sighting (observer's initial estimate of herd size), by year and sighting method, for sightings that did (green) and did not (black) lead to sets. Vertical bars show the median +/- the median absolute deviation about the median.

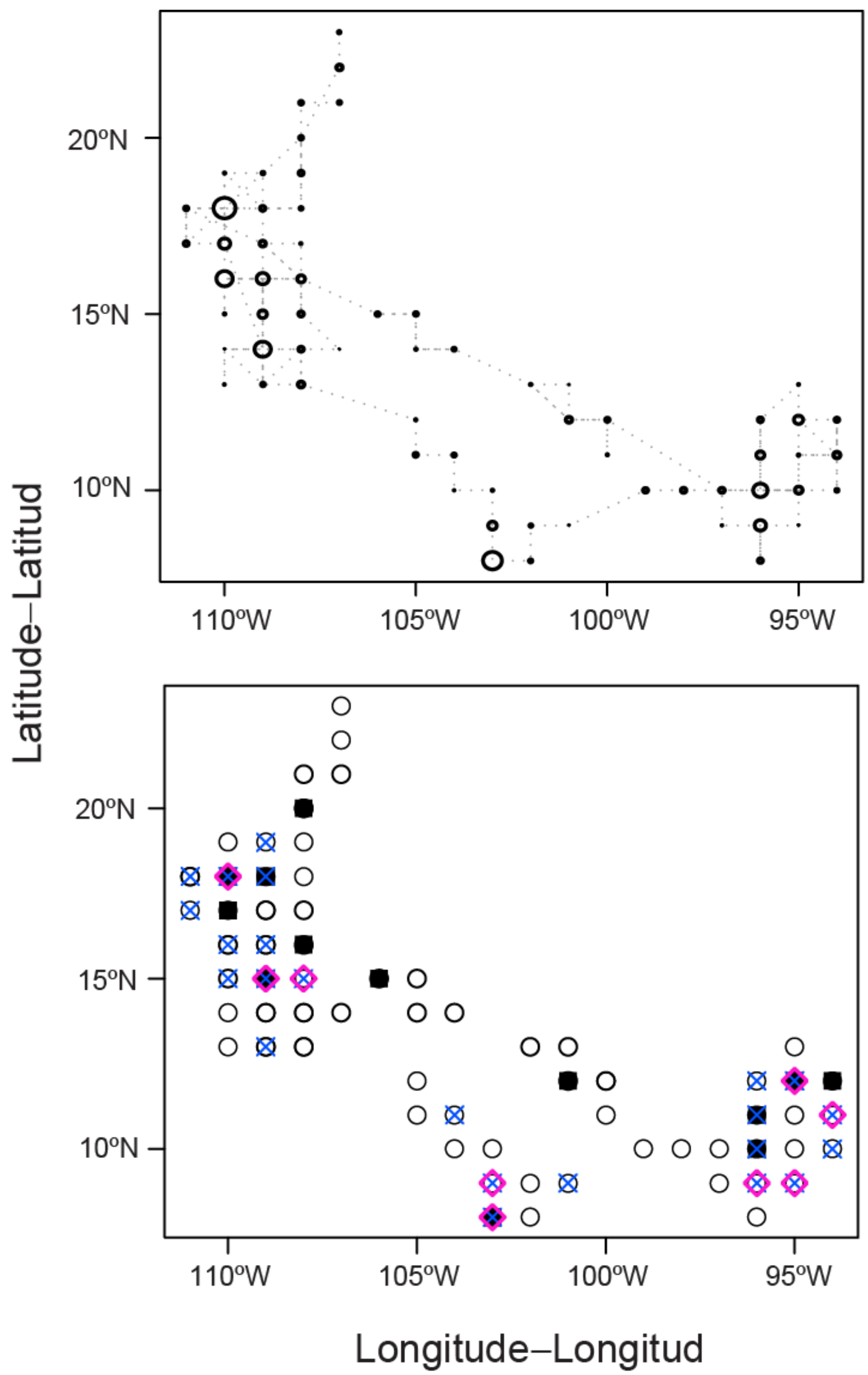

FIGURE 6. Search effort trajectory for an individual trip. Top panel: 1° areas with search effort, where black open circle size is proportional to amount of effort, and gray dotted line connects 1° areas through time. Bottom panel: solid black circles indicate non-set sightings, blue crosses indicate set-sightings, and pink diamonds indicate helicopter sightings.

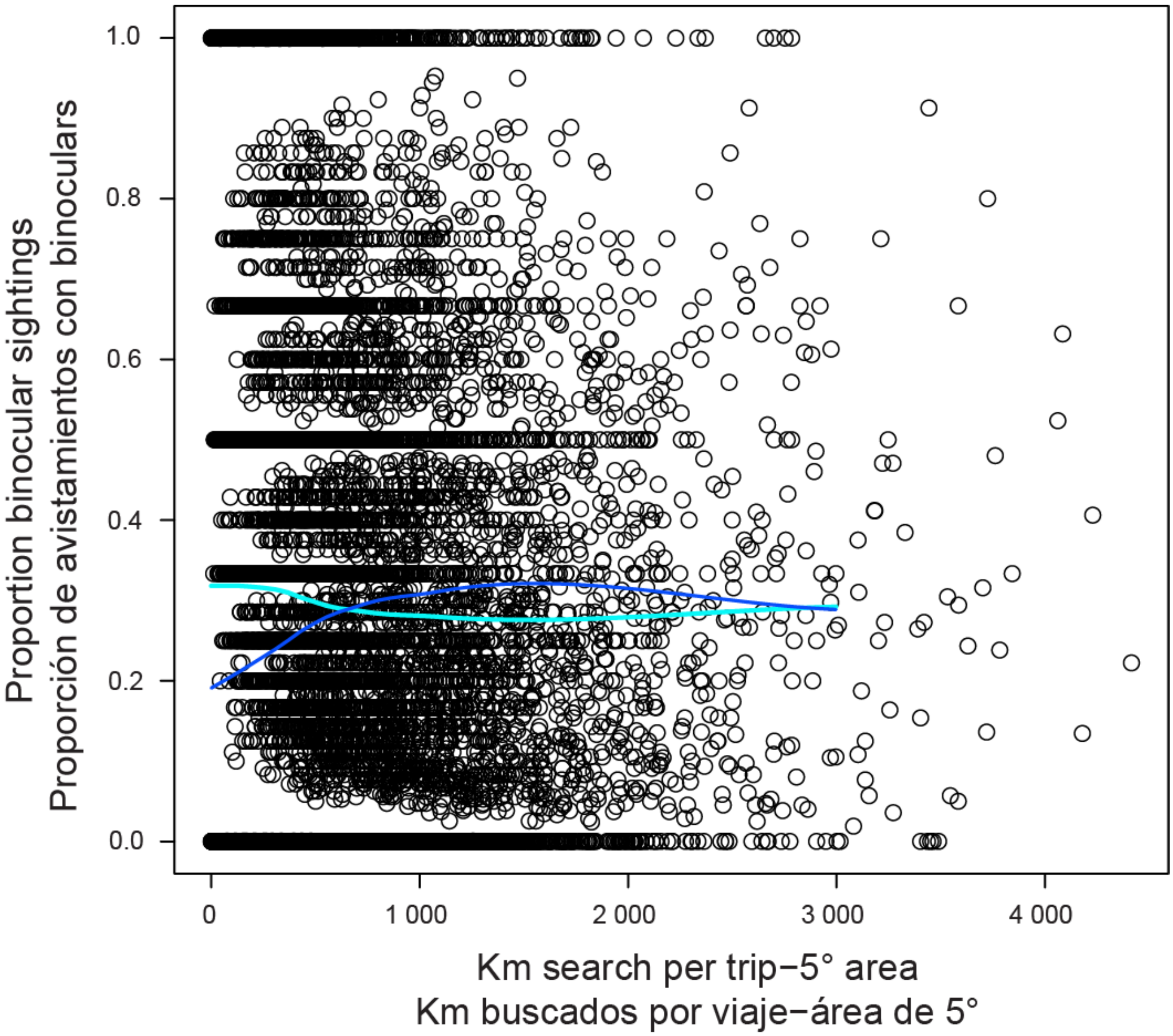

FIGURE 7. Proportion of binocular sightings by kilometers searched per trip - 5° area (black circles). The turquoise and dark blue lines show the overall trend in the proportion of binocular and helicopter sightings, respectively.

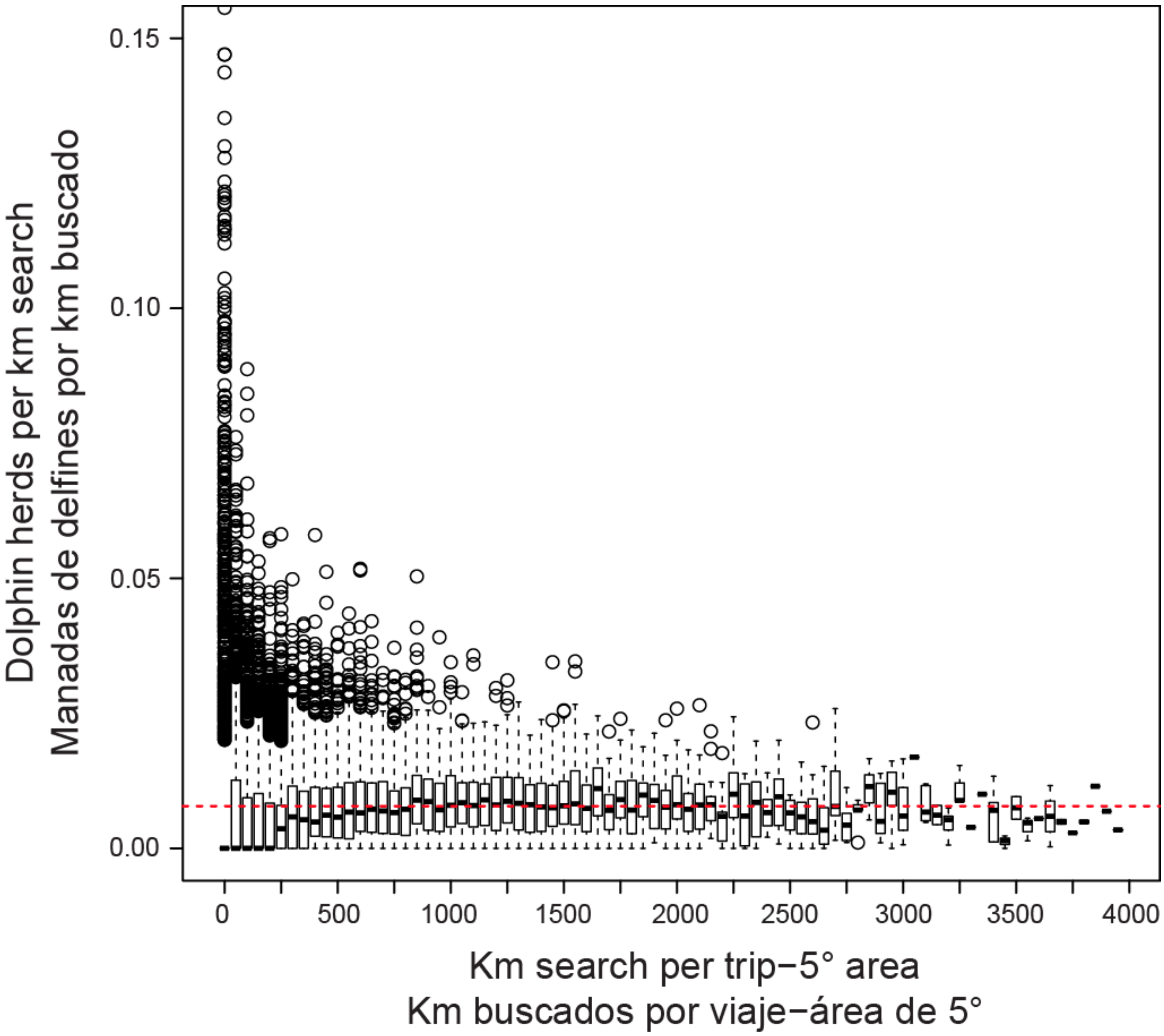

FIGURE 8. Box-and-whisker plot of encounter rate (number of dolphin herds per kilometer searching), grouped by trip-5° area. The red dashed line indicates the overall mean encounter rate. The y-axis was truncated at 0.15 to show detail.

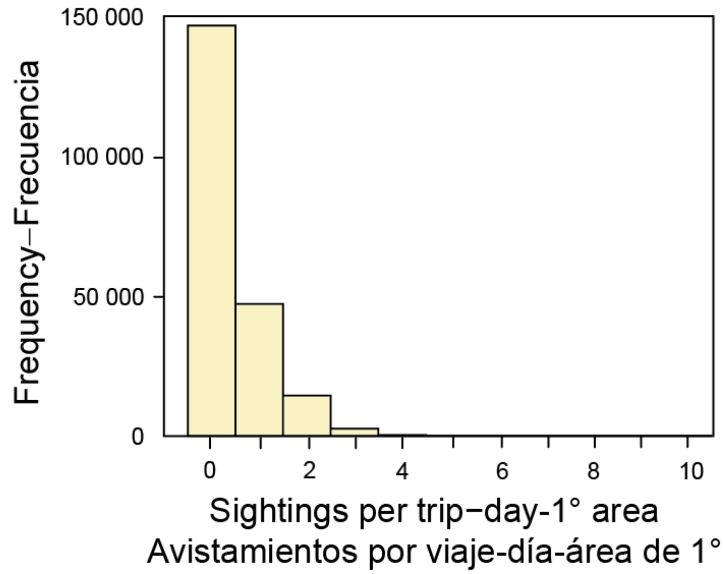

FIGURE 9. Number of dolphin herd sightings, per trip-day-1° area, 1990-2013.

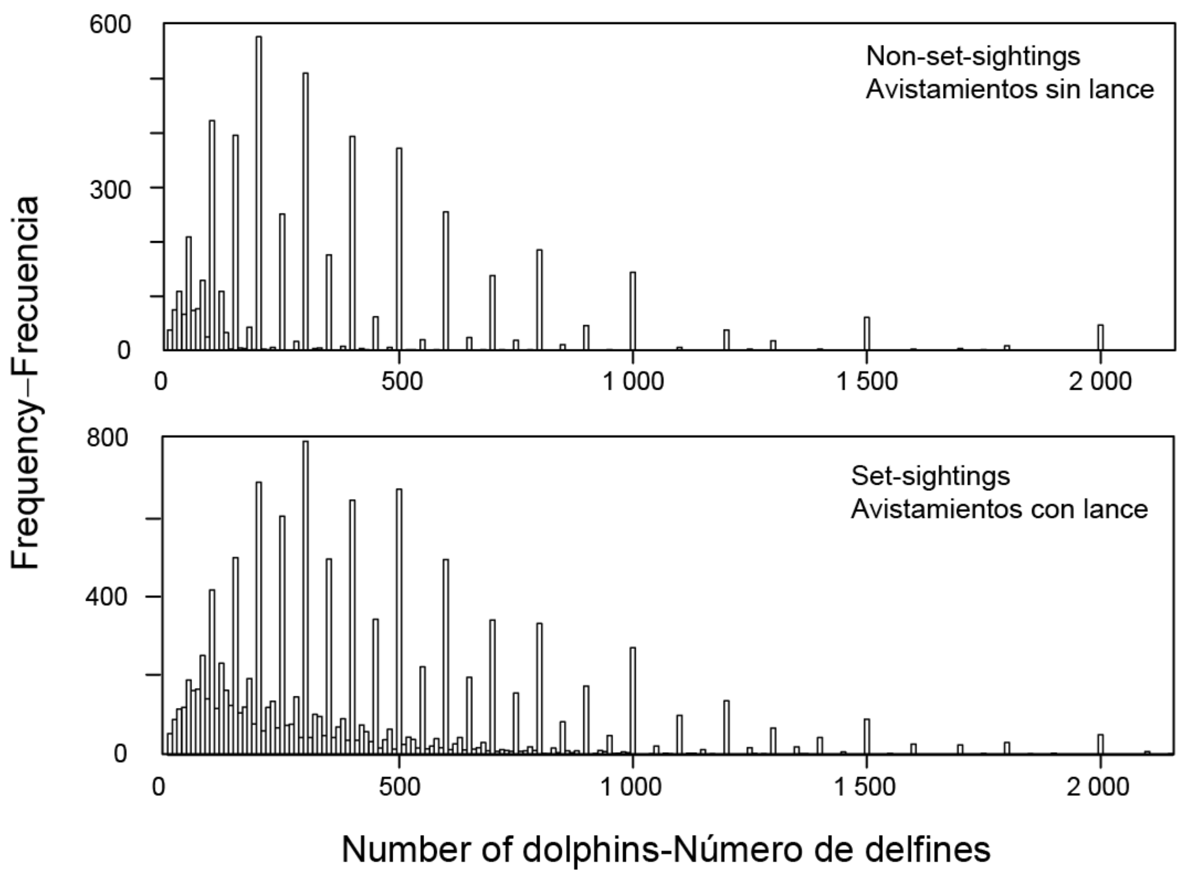

FIGURE 10. Number of dolphins per herd (radar sightings, pure northeastern spotted dolphin herds), for non-set-sightings (top panel; based on observer's initial estimate) and set-sightings (bottom panel; based on observer's best estimate) (x-axes truncated at 2,000 dolphins to show detail).

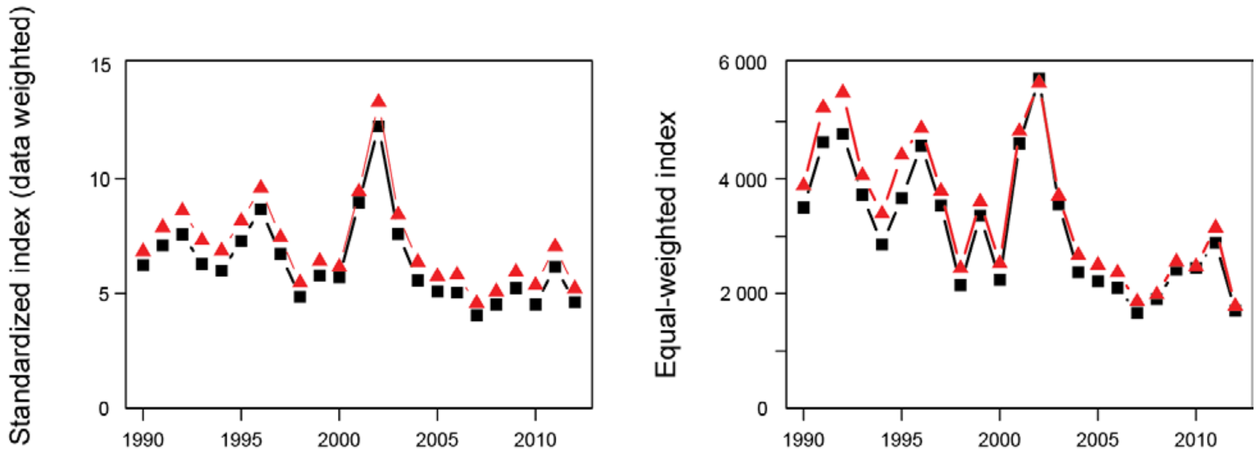

FIGURE 11. Indices of relative abundance for the northeastern offshore spotted dolphin. Left panel: data-weighted indices; right panel: equal-weighted indices. Black squares: based only on set-sightings; red triangles: all sightings within 20 nm of the vessel that had an observer initial estimate of herd size and species composition.

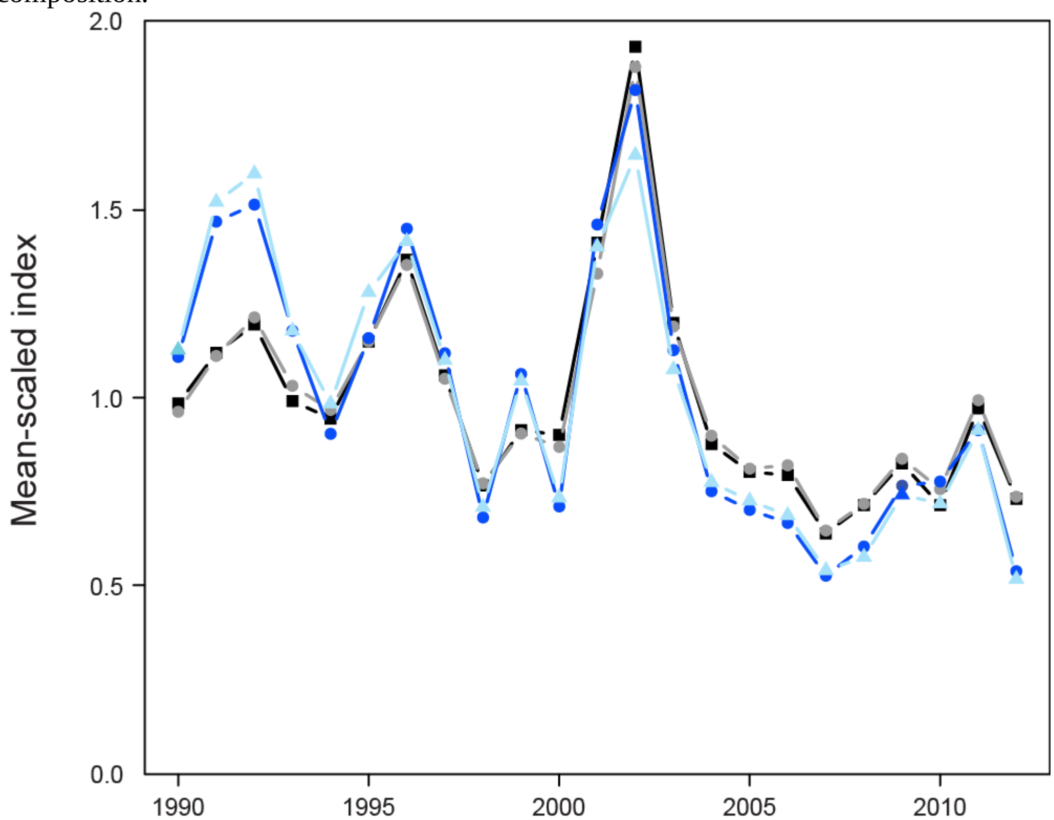

FIGURE 12. Mean-scaled relative indices from Figure 11. Black squares/gray circles: data-weighted; dark blue circles/light blue triangles: equal-weighted.

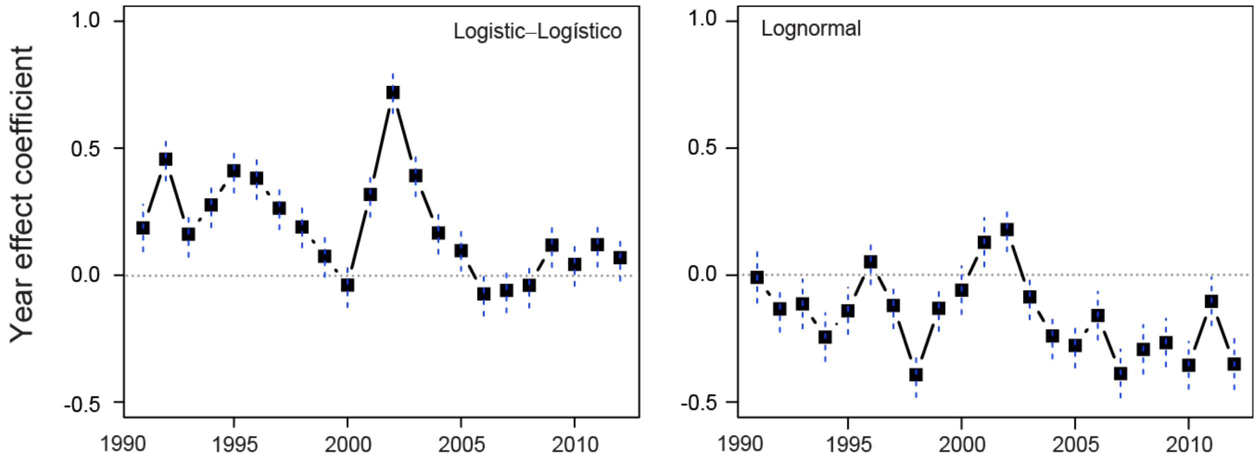

FIGURE 13. Year-effect coefficients for the delta-lognormal GAM fitted to all years (dashed lines indicate +/- 1.96·s.e.).

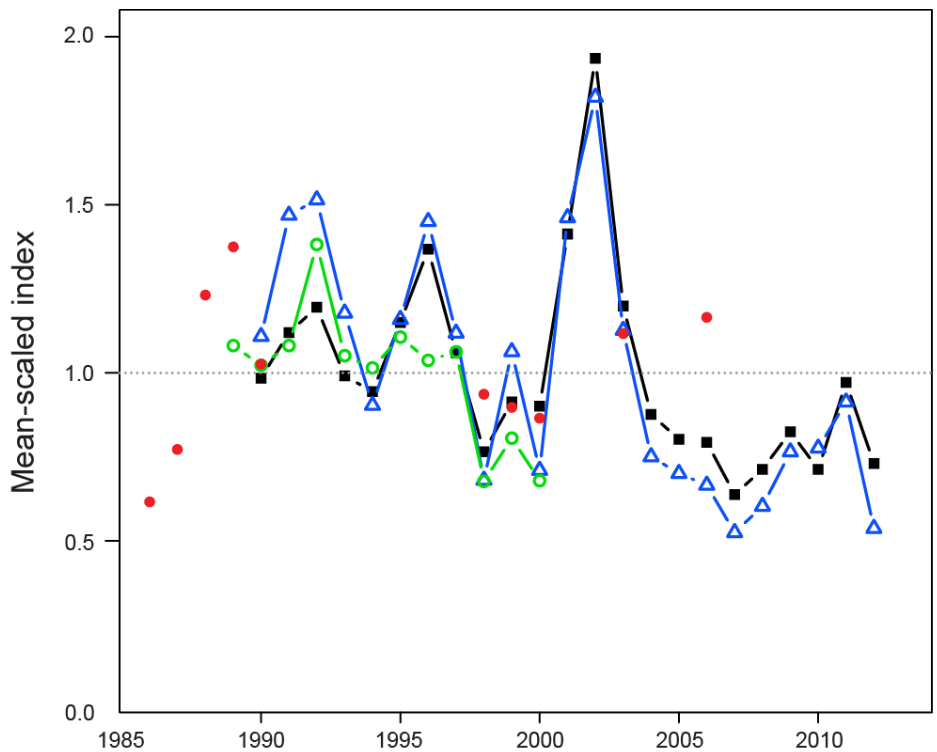

FIGURE 14. Mean-scaled relative indices from purse-seine data (solid black squares/open blue triangles: data-weighted and equal-weighted lognormal GAMs for set-sightings, Figure 12; open green circles: line transect index based on vessels with both radar and helicopter onboard, from Table 3 of Lennert-Cody *et al*. 2001), and NMFS survey estimates (solid red dots, from Gerrodette *et al*. 2008).

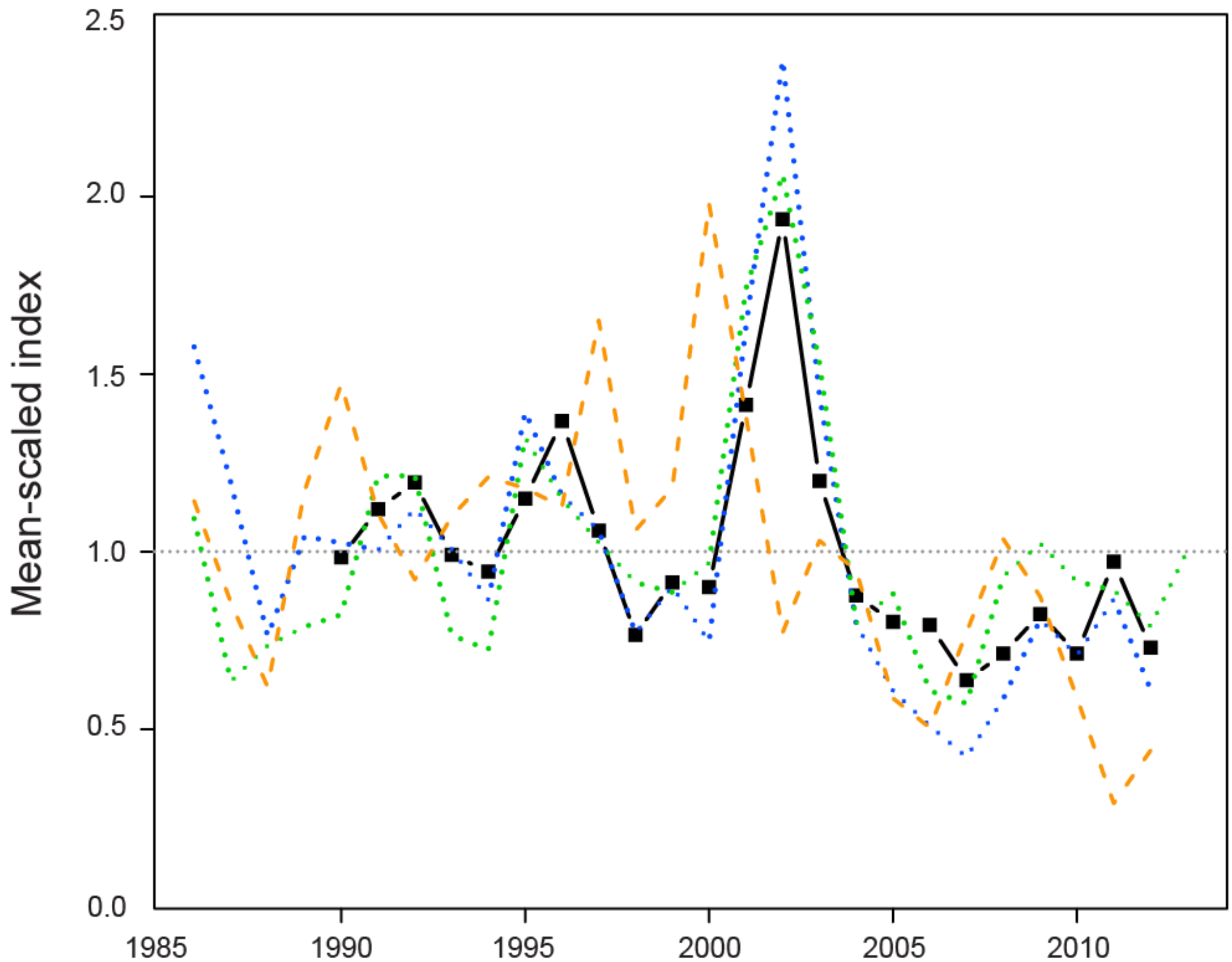

FIGURE 15. Mean-scaled index of relative abundance for the northeastern offshore spotted dolphin (solid black squares; data-weighted, set-sightings), mean-scaled purse-seine indices of relative abundance for yellowfin tuna (blue dotted line: standardized index from Lennert-Cody *et al*. 2013; green dotted line: nominal CPUE from Minte-Vera *et al*. (2014)), and mean-scaled longline index of relative abundance for yellowfin tuna (orange dashed line, standardized index from Minte-Vera *et al*. (2014)).

TABLE 1. Number of trip-day-1° areas with search effort ("observations"), numbers of offshore spotted dolphin sightings that led to sets, and numbers of offshore spotted dolphin sightings within 20 nm of the vessel, by year, in the northeastern spotted dolphin area. The column "Number of sightings within 20 nm" refers to those sightings with either an observer's initial estimate or best estimate of dolphin herd size and species composition.

Year	Number of observations	Number of set-sightings	Number of sightings within 20 nm
1990	5,412	1,124	1,482
1991	5,736	1,347	1,726
1992	7,849	2,279	2,904
1993	7,551	1,590	2,198
1994	7,516	1,755	2,327
1995	7,343	2,107	2,680
1996	9,187	2,510	3,106
1997	9,882	2,364	2,987
1998	13,277	2,796	3,653
1999	12,765	2,456	3,155
2000	9,886	1,771	2,219
2001	7,057	1,678	1,947
2002	9,275	3,098	3,527
2003	10,620	2,679	3,229
2004	11,963	2,481	3,085
2005	14,018	2,985	3,707
2006	10,886	1,778	2,354
2007	9,699	1,748	2,219
2008	8,770	1,595	1,964
2009	8,348	1,836	2,208
2010	9,965	1,950	2,385
2011	8,192	1,740	2,076
2012	7,211	1,437	1,741
Total	212,408	47,104	58,879