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Size composition and spatial distribution of shortfin mako sharks by size and sex in U.S. West Coast fisheries[1]

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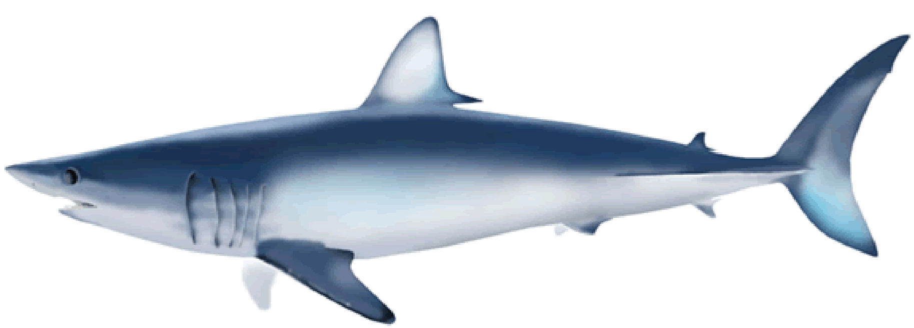

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ABSTRACT

The objective of this working paper is to examine the size composition and the sex and size-specific spatial distribution of mako sharks from U.S. West Coast fisheries. This information will help the ISC SHARKWG better understand the size and sex segregation, if any, of this stock and help in the development of the assessment model structure. The size compositions and spatial distributions of mako sharks along the U.S. West Coast was developed from four data sources: 1) market size samples of landed mako sharks from the drift gillnet fishery; 2) onboard observers of the drift gillnet fishery; 3) conventional tag deployments, primarily from the recreational fishery; and 4) size samples and satellite tag tracks from SWFSC juvenile shark longline surveys. Size compositions from the drift gillnet fishery, juvenile shark longline survey, and the conventional tag reports show that mako sharks from U.S. West Coast fisheries are primarily juveniles and sub-adults. The length distributions of males and females were similar from all data sources. A slight bias in the sex ratio towards male makos was observed, with approximately 1.2 to 1.3 males per female. Juvenile and sub-adult mako sharks did not show substantial sex-specific differences in their spatial distribution in the eastern North Pacific Ocean.

Based on these preliminary results, if an age-structured model is used for the upcoming mako shark assessment, we recommend the SHARKWG consider having the U.S. West Coast fisheries share a single selectivity and fit the selectivity to the most robust size composition data that represents the catches of the most important fisheries on the U.S. West Coast, notably the drift gillnet fishery. If a sex-specific model is used for the assessment, the SHARKWG could consider using a shared selectivity curve for both sexes, albeit with an offset for the male or female selectivity, in order to represent the slight bias towards males in these U.S. West Coast fisheries. Relative to the large spatial scales relevant in the upcoming stock assessment, we do not observe strong sex and/or size specific differences in the spatial distribution of mako sharks in the NEP. However, this conclusion is specific only for the size classes observed in this study – namely juvenile and sub-adult makos of both sexes, and the range of the data we examined. It should also be noted that these datasets lack sufficient adult female sample sizes to make robust conclusions about their spatial distribution.

INTRODUCTION

Shortfin mako sharks (*Isurus oxyrinchus*) are currently not a primary target species for any commercial fishery along the U.S. West Coast. However, the U.S. West Coast drift gillnet fishery catches non-negligible numbers of mako shark (Teo et al. 2011) and an experimental California-based longline fishery previously targeted blue and mako sharks during 1988-1991 (O’Brien and Sunada 1994). Furthermore, the recreational fishery on the U.S. West Coast occasionally targets mako sharks. These fisheries operate along the U.S. West Coast within the U.S. EEZ. The Southwest Fisheries Science Center (SWFSC) of NOAA Fisheries also conducts an annual scientific shark longline survey for juvenile sharks in Southern California waters, during which sharks are counted, measured and tagged. Based on these data sources, the size composition and spatial distribution of mako sharks by sex and size are examined in this document.

The Shark Working Group (SHARKWG) of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) plans to conduct a stock assessment of shortfin mako sharks in the North Pacific in 2014. The information on the size composition and spatial distribution of mako sharks along the U.S. West Coast will help the SHARKWG better understand the size and sex segregation, if any, in this stock and help in the development of the assessment model structure.

MATERIALS AND METHODS

Data Sources

Four sources of data were used to develop the size compositions and spatial distributions of mako sharks along the U.S. West Coast: 1) market size samples of landed mako sharks from the drift gillnet fishery; 2) onboard observers of the drift gillnet fishery; 3) conventional tag deployments, primarily from the recreational fishery; and 4) size samples and satellite tag tracks from SWFSC juvenile shark longline surveys. Although size composition data from the experimental longline fishery is not currently available, important information on the size distribution and sex ratio from this fishery can be gleaned from O'Brien and Sunada (1994), which reviewed this fishery.

The drift gillnet fishery operates within the U.S. EEZ along the U.S. West Coast (Fig. 1). Although management measures have changed the area of fishing operations over the years, the majority of the fishing effort occurs in the Southern California Bight. Details on the drift gillnet fishery can be found in Hanan et al. (1993) and Teo et al. (2011). The recreational fishery, experimental longline fishery and the juvenile shark survey is concentrated in the U.S. waters of the Southern California Bight (Fig. 1).

Size Compositions

Size samples from the abovementioned data sources came in a variety of length measurements: 1) fork lengths (FL, cm); 2) total lengths (TL, cm); and 3) alternate lengths (AL, distance between the first and second dorsal fins, cm). Measurements in TL and AL were converted to FL prior to analysis using the following equations developed from size sampling during the gillnet fishery and juvenile shark survey (Wells et al. 2013):

$$FL = (TL * 0.913) – 0.397, r^2=0.986 \ (n=2,177)$$
$$FL = (AL * 2.402) + 9.996, r^2=0.957 \ (n=3,250).$$

Size sample data were compiled from market samples of mako sharks caught by the drift gillnet fishery from 1981-1990. These samples were made primarily in AL and non sex-specific because typically only trunks were retained for market. Onboard observers recorded the FL and sex of mako sharks caught by the drift gillnet fishery from 1990 to 2012. The sex-specific size compositions were compiled by combining the market samples and observer data from the drift gillnet fishery. The sex-specific size composition from conventional tag reports (1977-2012) and the shark longline survey (1993-2011) were also compiled for both these data sources. It should be noted that the lengths from the conventional tag reports were primarily visually estimated by recreational fishermen, while the lengths from the juvenile shark survey were measured by SWFSC scientists.

Spatial Distribution

The spatial distribution of drift gillnet effort and mako shark catches recorded by onboard observers and the calculated catch-per-unit-effort (CPUE) were plotted by sex and size class. Kernel density rasters of catch (number of fish) and effort (length of gillnet in fathoms), were calculated by sex and size class using ArcGIS v10.1 (ESRI Inc.) and the Spatial Analyst Toobox (search radius ~ 3 degrees). The CPUE (fathoms of net per degree squared) was calculated as the catch density raster divided by the effort density raster, in areas with at least 1000 fathoms of net deployed per degree squared. Female and male makos were considered juvenile when their FL was <101 cm. Females were considered subadult when they were from 101 to 248 cm FL, and adults when they were ≥249 cm FL. Males were considered subadult when they were from 101 to 179 cm FL, and adults when they were ≥180 cm FL.

In addition, Argos-derived locations of mako sharks tagged with radio-transmitting satellite tags (SPOT; Wildlife Computers Inc.) during the shark longline surveys were plotted by sex and size class to examine the spatial distribution of these makos.

RESULTS AND DISCUSSION

Size Compositions

The size compositions from the drift gillnet fishery, juvenile shark longline survey, and the conventional tag reports show that mako sharks from U.S. West Coast fisheries are primarily juveniles and sub-adults (Fig. 2). The length distributions of males and females were similar from all data sources although the mean length of males and females from drift gillnet samples was approximately 10 cm larger than recreational and juvenile shark survey samples. This suggests that the selectivities for these fisheries are similar and may be modeled as fisheries with shared selectivities or aggregated into a single U.S. West Coast fishery, if necessary.

O'Brien and Sunada (1994) reported that the AL of mako sharks caught by the experimental longline fishery during 1988-1991 ranged from 19 to 102 cm (N = 3719 fish). The mean AL of males ranged from 47.0 cm (~123 cm FL) in 1988 to 50.0 cm (~130 cm FL) in 1991, while it was 47.0 cm (~123 cm FL) in 1988 to 49.7 cm (~129 cm FL) in 1991 for females. It was also noted that two distinct modes were present at 42 and 53 cm AL (111 and 137 cm FL) during each year of the fishery. In general, the size composition of the experimental longline fishery appear to be similar to the drift gillnet fishery although the mean FL was approximately 10 cm large for the longline fishery.

If we assume that there was no sampling bias with respect to sex in these data sources, the observed male:female ratios were 0.9, 1.2 and 1.3 for the conventional tag reports, drift gillnet fishery, and shark longline survey, respectively (Fig. 2). This is similar to the 1.3 (1988 and 1990) and 1.2 (1989 and 1991) males per female reported by O'Brien and Sunada (1994). This suggests a slight bias towards male makos, with a slightly higher selectivity for males relative to females in U.S. West Coast fisheries.

Spatial Distribution

Although there was drift gillnet effort throughout U.S. waters off the California, Oregon, and Washington coasts, most of the effort occurred in the Southern California Bight (Fig. 3). Importantly, juvenile and sub-adult mako sharks did not show substantial sex-specific differences in the spatial distribution of capture locations (Fig. 4) and CPUE (Fig. 5). Both male and female juvenile mako sharks were primarily caught in the Southern California Bight, although sporadic catches occurred throughout the California Current Ecosystem. The sub-adult mako sharks were similarly distributed as the juvenile makos, with higher catches and CPUE in the Southern California Bight. Substantially fewer adult females were caught by the drift gillnet fishery relative to the males (Fig. 4). This was likely due to the much larger median size at 50% maturity for female makos and similar size selectivity for both sexes. The limited spatial distribution shown in Figs. 4 and 5 can be attributed to the relatively limited spatial distribution of the fishery, which is constrained to the U.S. EEZ. It should be noted that an apparent offshore hotspot with high CPUE at approximately 123°W and 33°N (Fig. 6, most clearly seen in the adult females panel) is likely an artifact of the kernel density estimates due to the very low estimated effort density and non-negligible catch density in the area. A smaller search radius or limiting CPUE calculation to a higher minimum effort density would have reduced or eliminated this hotspot.

With the fishery-independent location data from SPOT tags deployed on mako sharks during the shark longline surveys, these sharks can be observed utilizing areas beyond the California Current Ecosystem (Fig. 6). They spent substantial amount of time in the California Current but some also migrated towards Hawaii, into the subtropical gyre. Relative to the likely spatial scale of the stock assessment, there does not appear to be substantial differences in the movement patterns of the subadult males and females, as well as adult males. Although the SPOT tag locations are limited to the Northeastern Pacific (NEP), conventional tags have shown that some mako sharks tagged in the NEP do migrate to the Western and Central Pacific, supporting a single North Pacific stock (Sippel et al. 2011).

Conclusions

Based on these preliminary results, if an age-structured model is used for the upcoming mako shark assessment, we recommend the SHARKWG consider having the U.S. West Coast fisheries share a single selectivity and fit the selectivity to the most robust size composition data that represents the catches of the most important fisheries on the U.S. West Coast, notably the drift gillnet fishery.

If a sex-specific model is used for the assessment, the SHARKWG could consider using a shared selectivity curve for both sexes, albeit with an offset for the male or female selectivity, in order to represent the slight bias towards males in these U.S. West Coast fisheries.

Relative to the large spatial scales relevant in the upcoming stock assessment, we do not observe strong sex and/or size specific differences in the spatial distribution of mako sharks in the NEP. However, this conclusion is specific only for the size classes observed in this study – namely juvenile and sub-adult makos of both sexes – and the range of the data. It should also be noted that these datasets lack sufficient adult female sample sizes to make robust conclusions about their spatial distribution.

ACKNOWLEDGEMENTS

We thank the many people who collected these data, including observers in the drift gillnet fishery, recreational anglers who tagged sharks, and participants of the shark longline survey cruises. We are also grateful to those who manage the databases used in this work.

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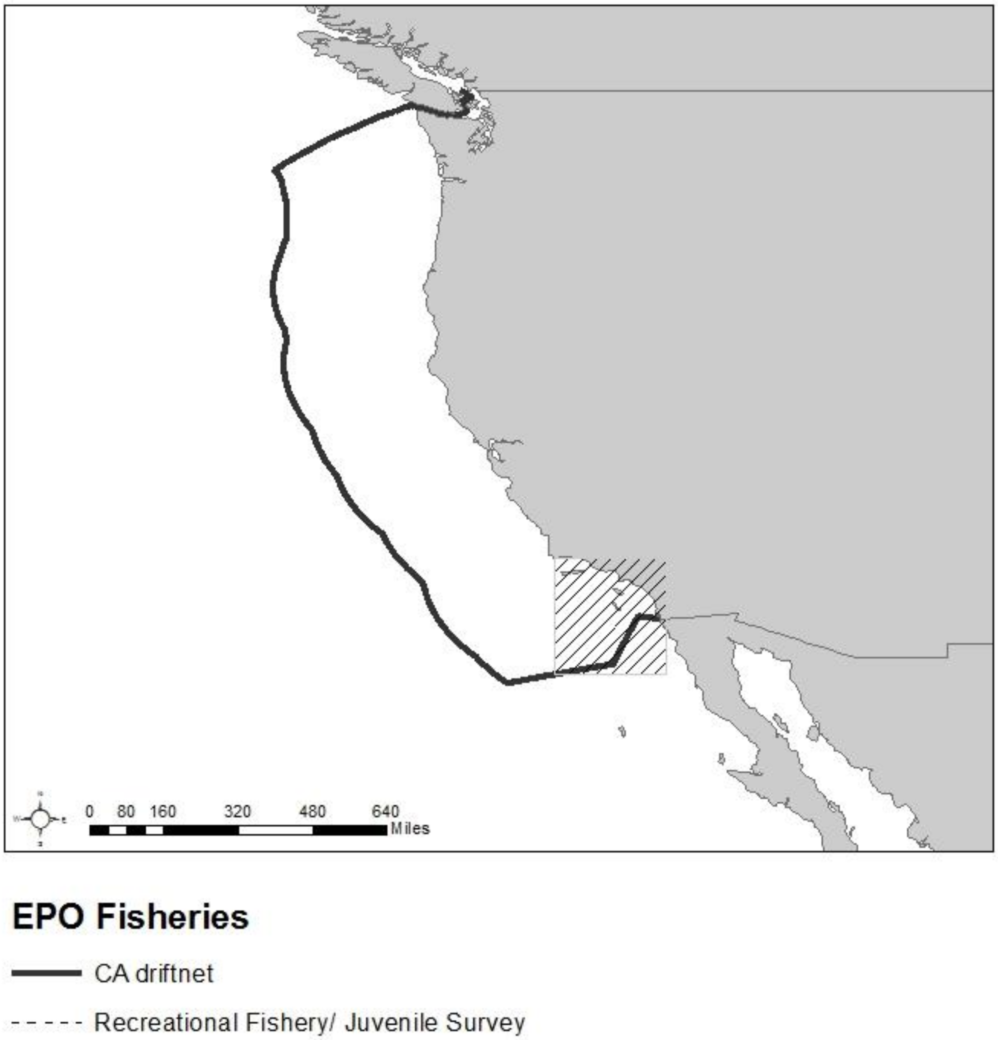

Figure 1. Map showing the approximate area of operations for the U.S. drift gillnet fishery, recreational fishery, and the juvenile shark longline survey.

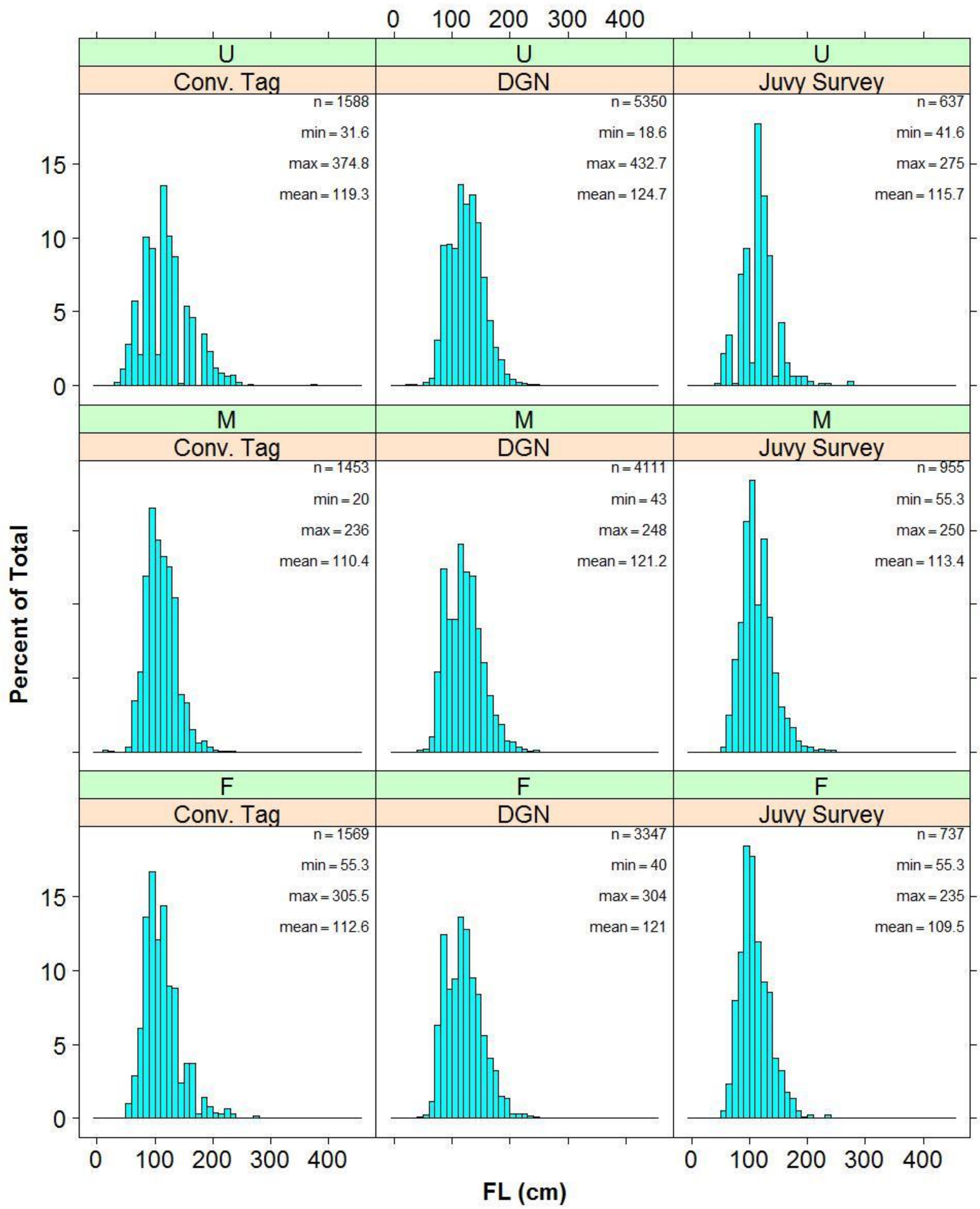

Figure 2. Sex-specific (U: unspecified sex; M: male; F: female) size compositions from conventional tag reports primarily from the recreational fishery (left column), drift gillnet fishery (middle column), and juvenile shark longline survey (right column). Number of samples (n), and the mean, minimum and maximum fork lengths of each histogram are shown in each panel.

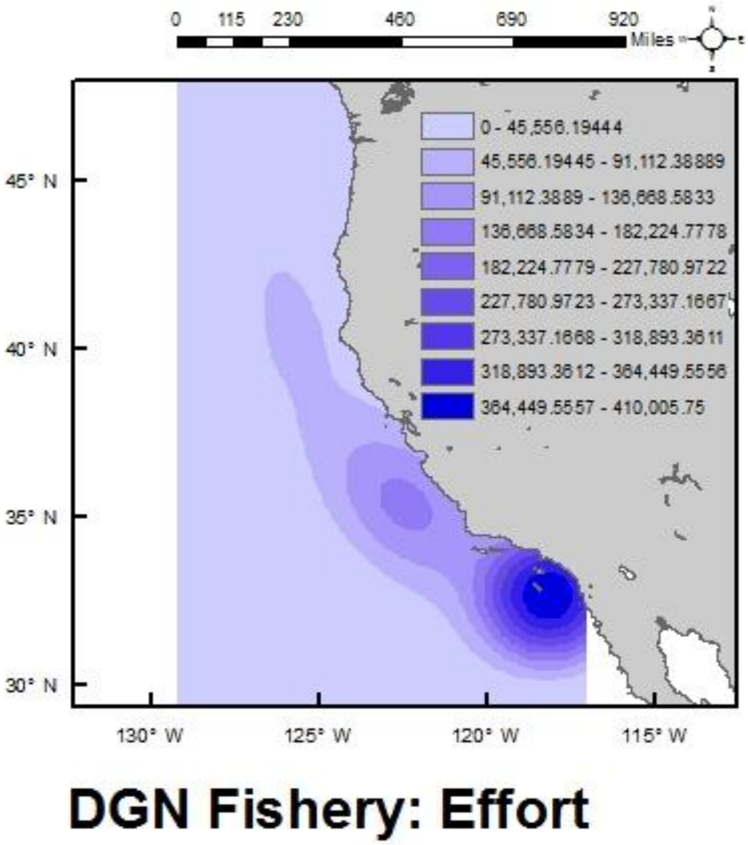

Figure 3. Map showing the kernel density of drift gillnet effort (fathoms of net per degree squared) recorded by onboard observers.

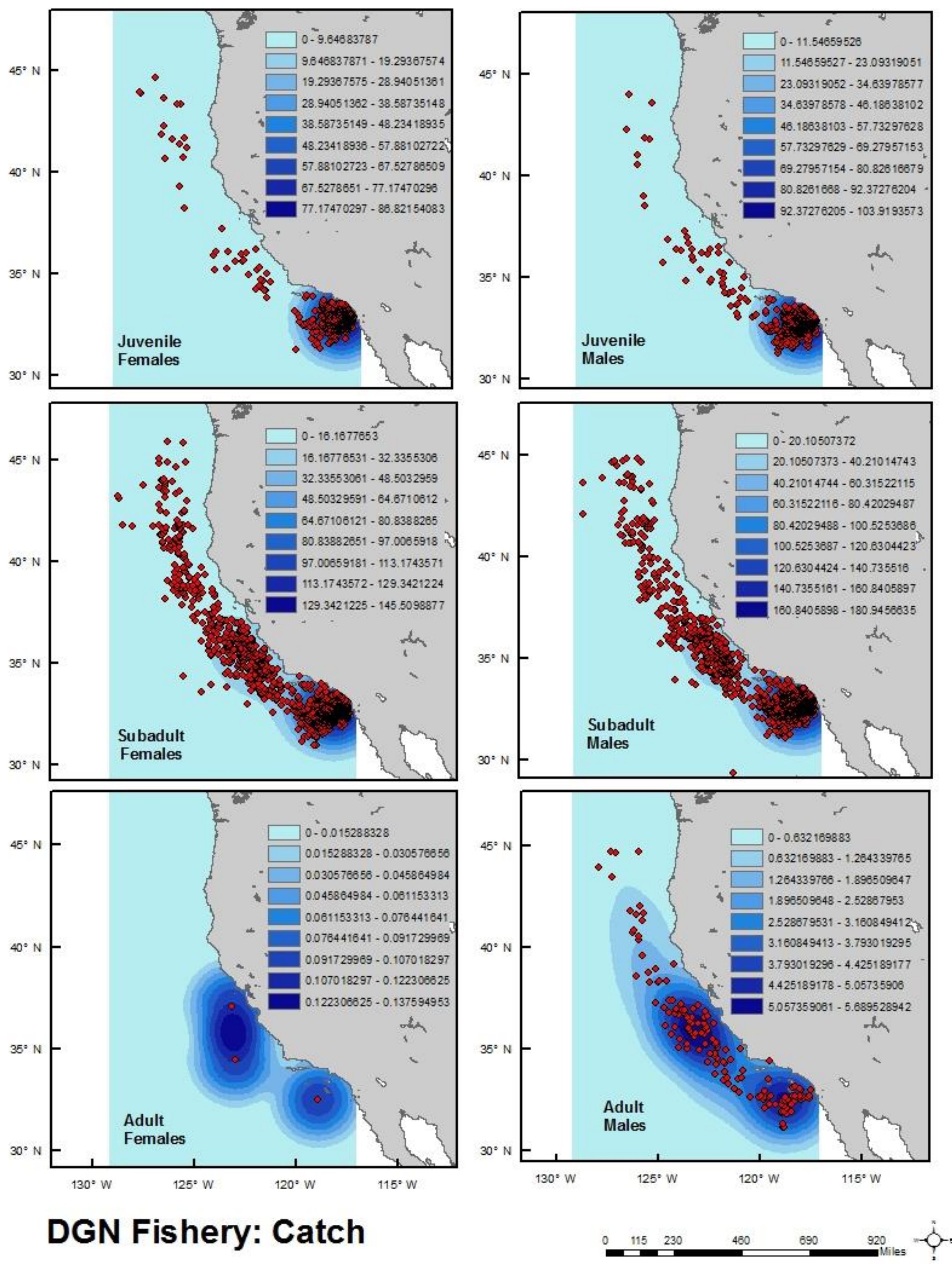

Figure 4. Map showing the locations of capture (red circles) reported by onboard observers of the drift gillnet fishery and kernel density of catch (number of fish per degree squared). Female (left column) and male (right column) distributions are shown by size class: juvenile (top row), subadult (middle row), and adult (bottom row).

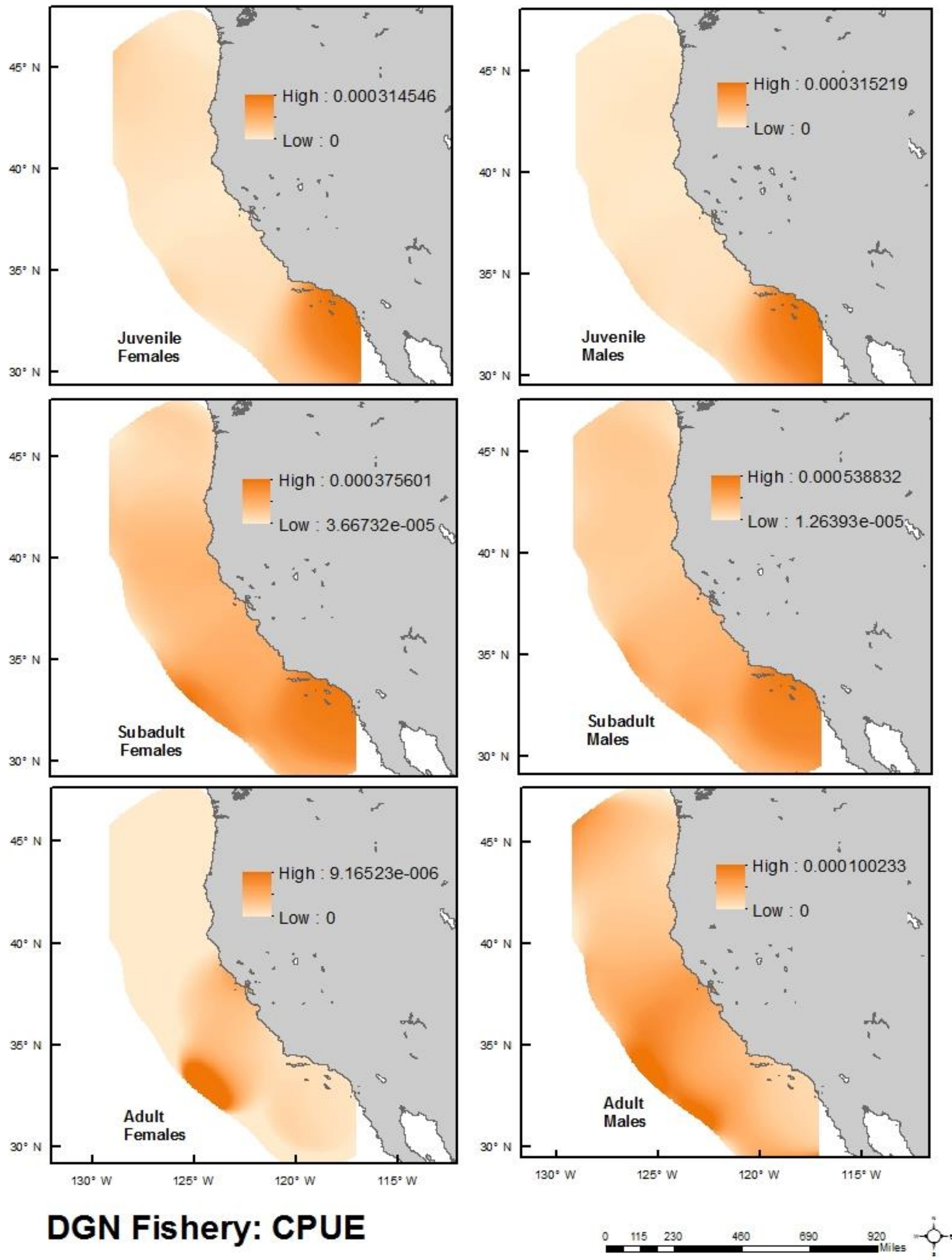

Figure 5. Map showing the estimated catch-per-unit-effort (number of fish per fathom of net deployed) for the commercial drift gillnet fishery. Female (left column) and male (right column) distributions are shown by size class: juvenile (top row), subadult (middle row), and adult (bottom row).

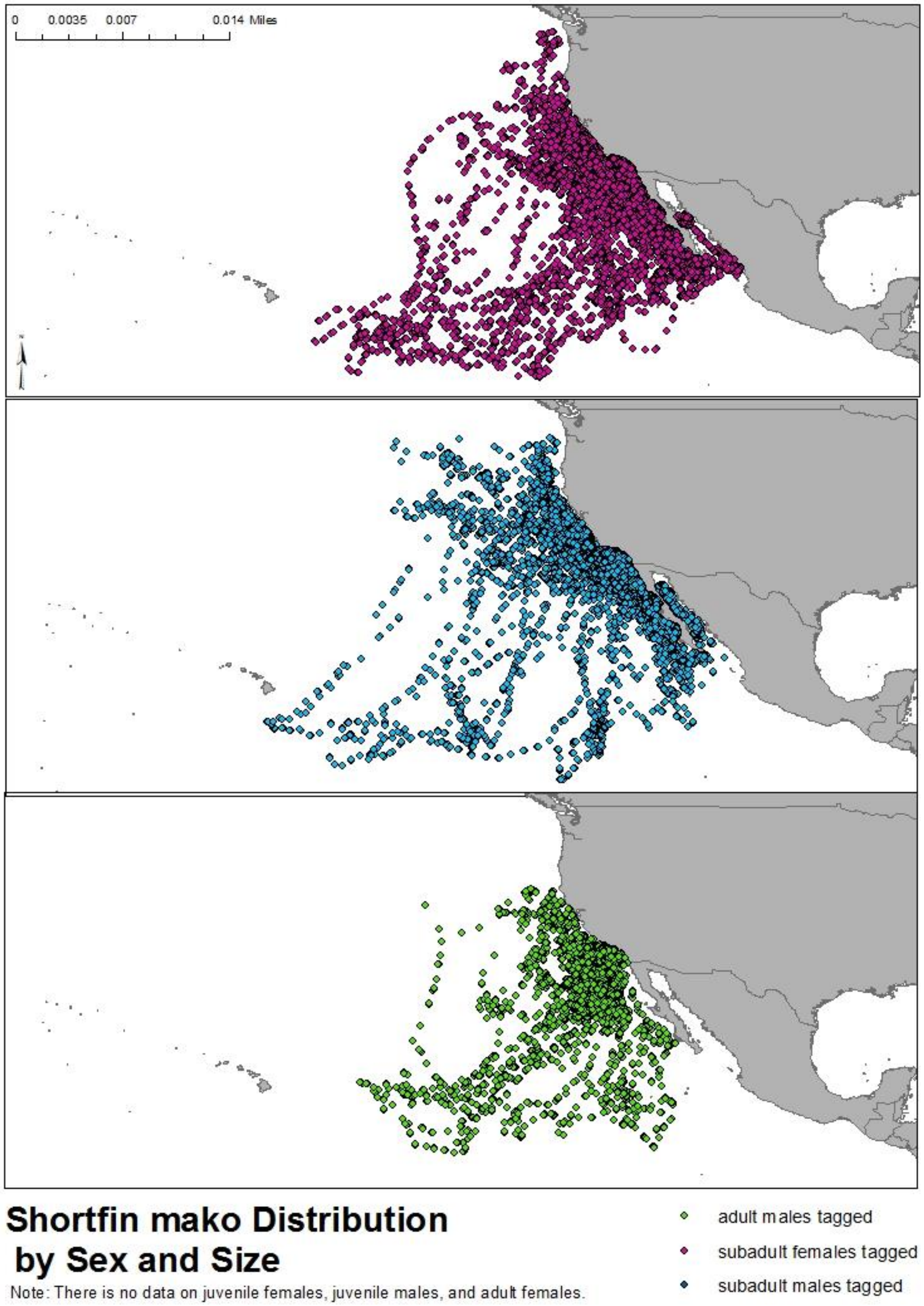

Figure 6. Locations of subadult female (n= 35; top row), subadult male (n=35; middle row), and adult male (n=11; bottom row) mako sharks that were tagged with SPOT tags during the juvenile shark longline survey.