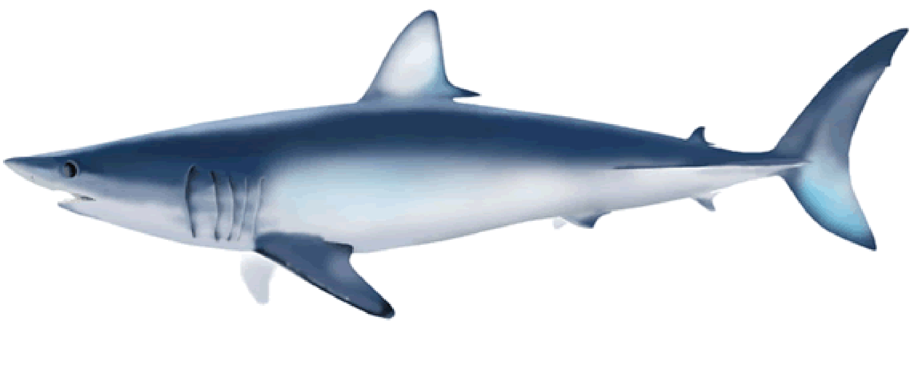
Distribution pattern of shortfin mako (*Isurus oxyrinchus*) caught by Kesennuma offshore longline fleets[1]

Ko Shiozaki, Yasuko Semba and Kotaro Yokawa

National Research Institute of Far Seas Fisheries

5-7-1, Orido, Shimizu-ku, ShizuokaCity, Shizuoka Pref. Japan



[1] Figures shown in this document are also provided in separate files.

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Executive summary

The distribution pattern of shortfin mako (*Isurus oxyrinchus*) was examined in relation to the environmental factors, on the basis of the size data collected by Kesennuma offshore longline fleet. The size and sex data with location and date was collected between 2005 and data from 60,769 individuals were used. It was suggested that the main component of catch was individuals smaller than 200 cm (PCL) and these individuals extensively distributed in Kuroshio Current, Kuroshio Extension and Transition area. The ontogenetic shift of distribution was suggested to occur; from waters off Japan (<100 cm) to western or southern area (≥100 cm). The strong evidence on the sexual difference in the distribution pattern and environmental preference was not found within the size range used here. However, considering that the record of adult female was very small, segregation of this component outside the fishing ground of this fleet and/or ontogenetic change of catchability may occur. Further investigation is necessary to clarify the distribution pattern of this species throughout its life span.

Introduction

Shortfin mako, *Isurus oxyrinchus*, is a highly migratory shark with worldwide distribution. Despite recent global concern and intensive ecological studies on this species, little is known about its distribution pattern. Some study suggests that this species exhibit sexual (Mucientes *et al*. 2009) and/or size (Semba and Yokawa 2011) segregation. Understanding the distribution and migration pattern play a significant role for size or age-based stock assessment modeling and management advice.

Kesennuma offshore longline fleet is the fishery which targets swordfish and blue shark depending on seasons. This fleet also catches shortfin mako as bycatch within these operations. We have begun program[2] to collect size and sex data of shortfin mako on board from Kesennuma offshore longline fleet since May 2005. Collating with the location and date for each size data, we attempted to describe the general distribution pattern of this species in the North Pacific by size and sex.

Materials and methods

Environmental data

The following data from several data sources were used.

- Sea surface height (SSH)

  Sea surface height data on daily basis was obtained as the form of the delayed-time updated maps of absolutedynamic topography (DT-UPD-MADT) of a merged altimeter satellite product, which was distributed by AVISO (Archiving, Validation and Interpretation of Satellite Oceanographic data) by CNES (Le Centre National d'EtudesSpatiales). The spatial resolution of the data is 1/3°x1/3° Mercator grids.

- Sea surface temperature (SST; observed data)

[2] The data in this program corresponds to the data of skipper's note introduced by Shiozaki *et al.* (2012).

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Data of sea surface temperature on daily basis was obtained from GHRSST/NCDC, which was distributed by NASA/PODAAC (http://podaac.jpl.nasa.gov/). This data was developed from multiple satellite and field buoy data and its spatial resolution is 1/3°.

For the individuals caught in the area east of the dateline, only sea surface height and sea surface temperature were used. The environmental data corresponding to the date and location of each catch was extracted and homologized with size and sex data.

Processing of size data

The 67,469 individuals were recorded from 16,124 operations between May 2005 and January 2013. Each data consists of precaudal length (PCL: cm), sex, date and location of capture. Of this, data from 6,700 individuals lacked any of size, sex, location and operation data, therefore, these data was removed from the analysis and 60,769 individuals were used. In this document, PCL was used as body length.

Based on the past document (Semba and Yokawa 2011), the North Pacific was divided into 4 subareas (Figure1). The oceanographic characteristic of each area is; area 1 contains Kuroshio Extension and transition area, area 2contains Kuroshio Current, Kuroshio Extension and transition area. The influence of Kuroshio Current is weakened in area 3 and area 4.

Regarding the season (indicated as "quarter"), the year was divided into four equal seasons: spring (Q1: January–March), summer (Q2: April–June), fall (Q3: October–December), and winter (Q4: July–September). On the basis of this spatial and temporal scale, the size frequency and relationship between catch number and environmental factors (SSH and SST) were described.

Results and Discussion

Figure2 shows the spatial and temporal change of catch number. This figure also indicates the temporal change of operating area for this fleet. As shown in this figure, the fleet changes the fishing area from the southern (spring and summer) to the northern (fall and winter) area. Longitudinally, to a lesser extent, temporal change was observed; from around 140°E-150°E (January to July) to around 170°E-180°E (October and November). This shift reflects the change of target species in longline from swordfish (winter) to blue shark (summer).

As indicated in Figure 3, the individuals smaller than 200 cm were dominant in the catch throughout the period. Males larger than 260cm was not caught throughout the period, meanwhile females larger than that were caught in small number. This result indicate that both juveniles and adults were caught in males, but almost majority of females were juvenile on the basis of known size at maturity estimated for population from the western and central North Pacific Ocean (Joung and Hsu 2005, Semba *et al*. 2011). Unless the catchability is different between the sexes, this result may indicate that adult females exhibit different distribution pattern from males, as suggested by Mucientes *et al*. (2009). In both sexes, juveniles between 100cm and 150cm were caught in large number between 2007 and 2009.

The spatial distribution of catch number was shown in Figure 4. Although it depends on the amount of effort, large catch was recorded roughly in two areas in both sexes; waters between 140°E and 160°E (off Japan) and

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170°E and 180°E (near dateline). From the viewpoint of ontogenetic stage, juveniles between 100cm and 150cm were caught most frequently in the water off Japan and, they were caught in the water near dateline to a lesser extent. Spatial difference in the size is also shown in size frequency by areas (Figure5). In area 1 and area 2, juveniles dominated in the catch in both sexes, whereas the ratio of adult increased in males in area 3 and area 4. Almost all of female catch was juveniles in all areas.

Quarterly size distribution by area was shown in Figure 6. In area 1 with relatively rich amount of data, the mode shifted by 10 cm in every quarter. Seasonal shift was less obvious in other areas.

Figure 7 indicates the relationship between size and SSH corresponding to each observation by area, season, and sex. Some seasonal or regional trend was observed regarding this relationship. In quarter 1in area 1, the amount of data is relatively small and small number of catch were recorded in high SSH environment (south of Kuroshio Extension; inside the Subtropical circulation). In area 1 and area 3 (north of 35° N), relatively high catch was recorded in low SSH (transition area; north of Kuroshio Extension) from quarter 2 to quarter 4. In area 2, many catch were recorded in high SSH environment in quarter1 and then area with positive catch tends to expand to low SSH environment, too. In area 4, less clear trend was observed due to the limitation of record.

Figure 8 indicates the relationship and SST corresponding to each observation by area, season, and sex. Generally, many catch was observed in the range between 15 and 20 ℃. In quarter 1, high catch was observed in area 2 (south of 35° N). In quarter 2, high catch was also recorded between 15 and 20 ℃, but sharks tend to be caught in higher temperature (>20℃) in area2 and area 4 (south of 35°N). In quarter 3, catch in warmer environment was also observed in area 1 and area 3 (north of 35°N). In quarter4, high catch was observed in area 3 compared to area 1. In both SSH and SST, sexual difference in the relationship was not clear.

Conclusion

This document indicates that the operation area of Kesennuma-fleet is distributed in wide range including Kuroshio Current, Kuroshio Extension and Kuroshio-Oyashio transition area. The size data collected by this fleet suggests that 1) the main component of shortfin mako caught by this fleet is juvenile; 2) the shortfin mako extends its distribution from waters off Japan to the eastern and/or southern areas as they grow and 3) sexual difference in the distribution pattern and environmental preference was not clear within the size range used in this document. The paucity of adults, especially females, prohibited to capture the comprehensive picture of distribution of this species. It is suggested that the investigation in the area outside the fishing ground of this fleet (i.e. subtropical to tropical area in the North Pacific) would progress our understanding of distribution of adults. The relationship with oceanographic data suggests the possibility of seasonal change of distribution pattern, which needs to be investigated on the basis of index such as CPUE by sex or ontogenetic stages and/or electronic tagging research in the future work.

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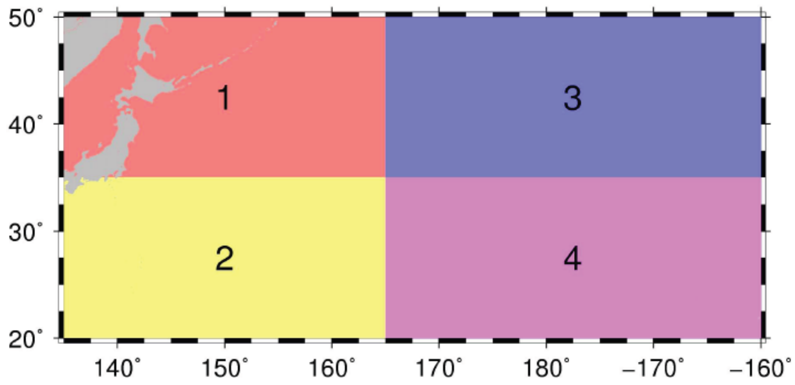

Figure 1. Subareas used in this document

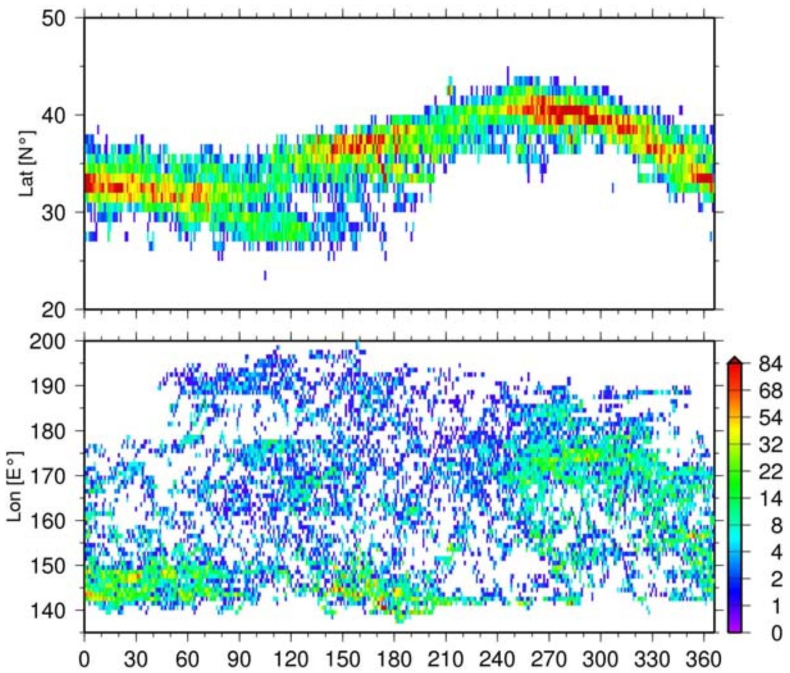

Figure 2.Thespatial and temporal change of catch number (color scale). X-axis is the serial date within a year. Y-axis of upper and lower figure denotes latitude and longitude, respectively. Color reflects the number of catch.

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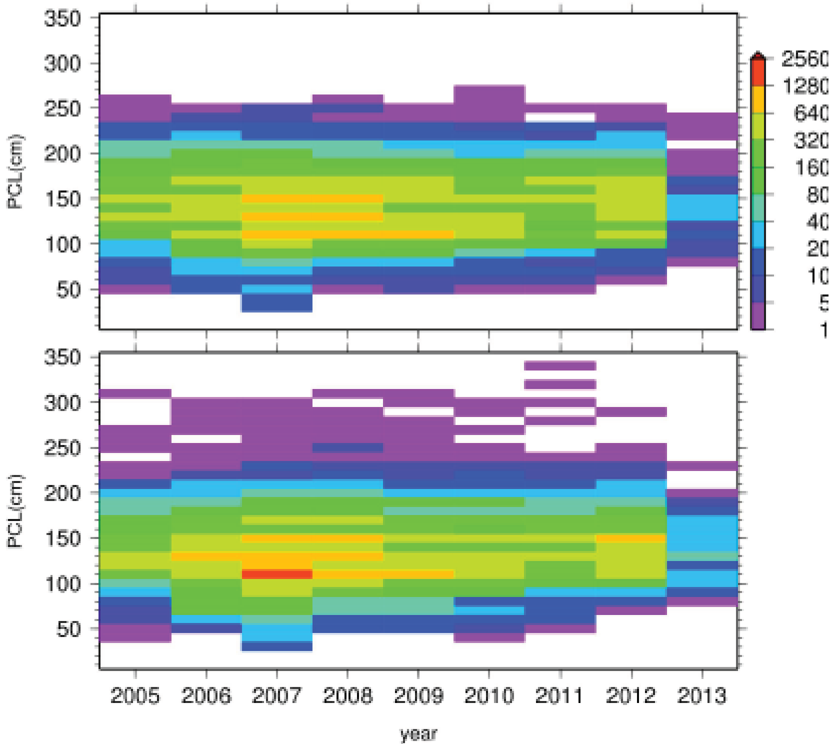

Figure 3. Distribution of size in males (upper) and females (lower) by year. The catch number in each size class (10 cm interval) was depicted by color.

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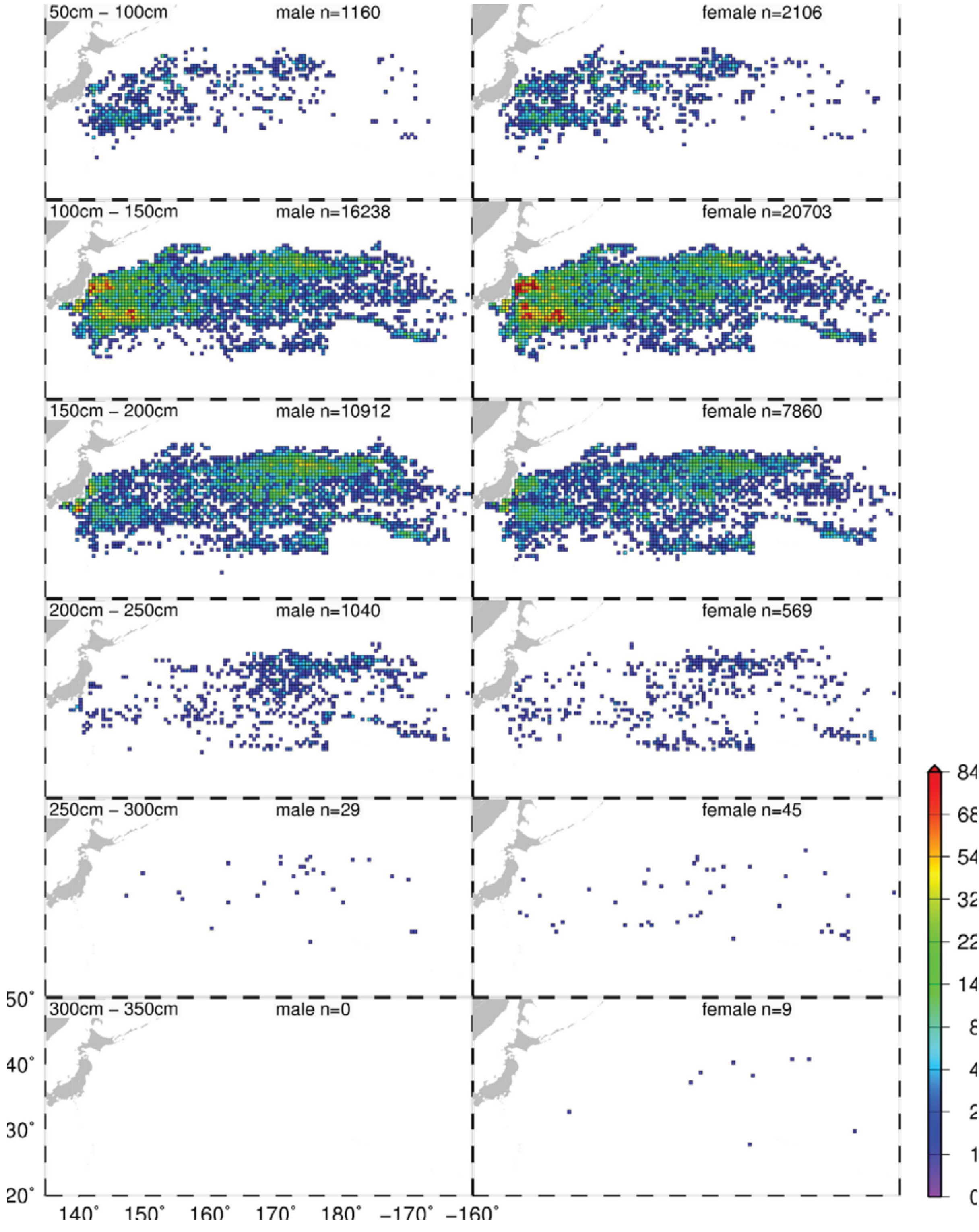

Figure 4. Location of catch by size class (50 cm interval) by sex.

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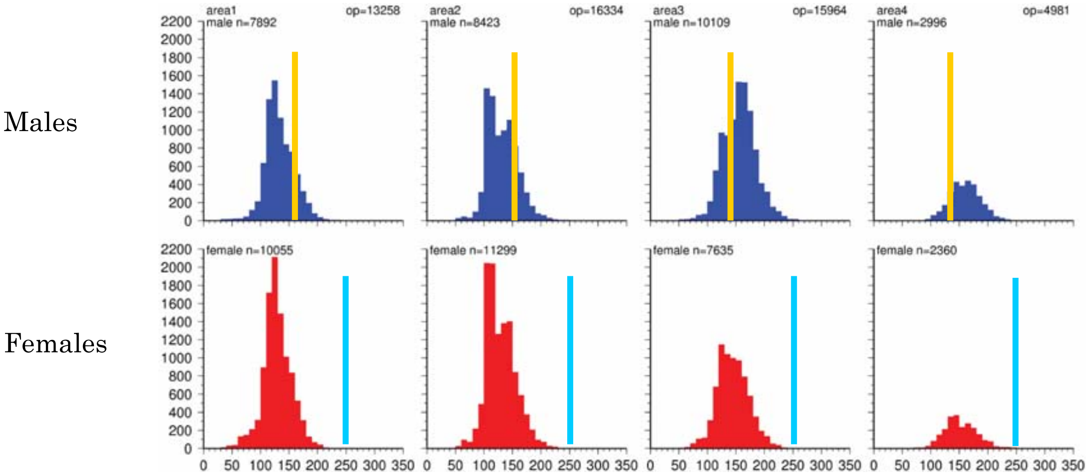

Figure 5. Sizefrequencies by area and sex. Yellow and blue lines indicate the size at maturity of males and females, respectively.

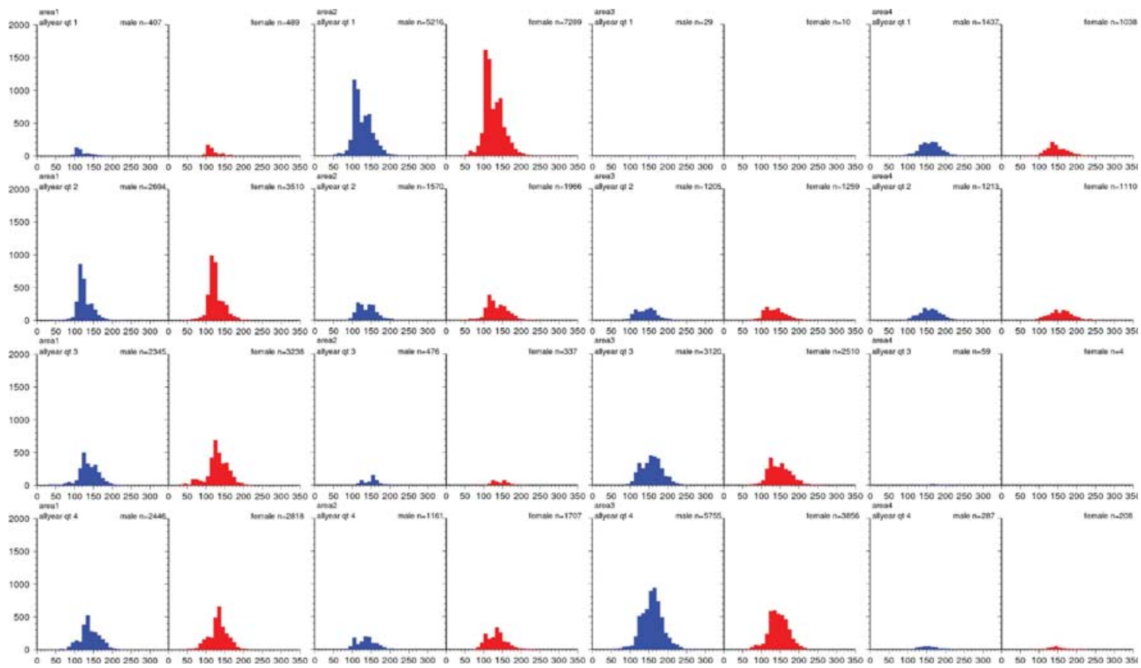

Figure 6. Quarterly size frequencies by area and sex.

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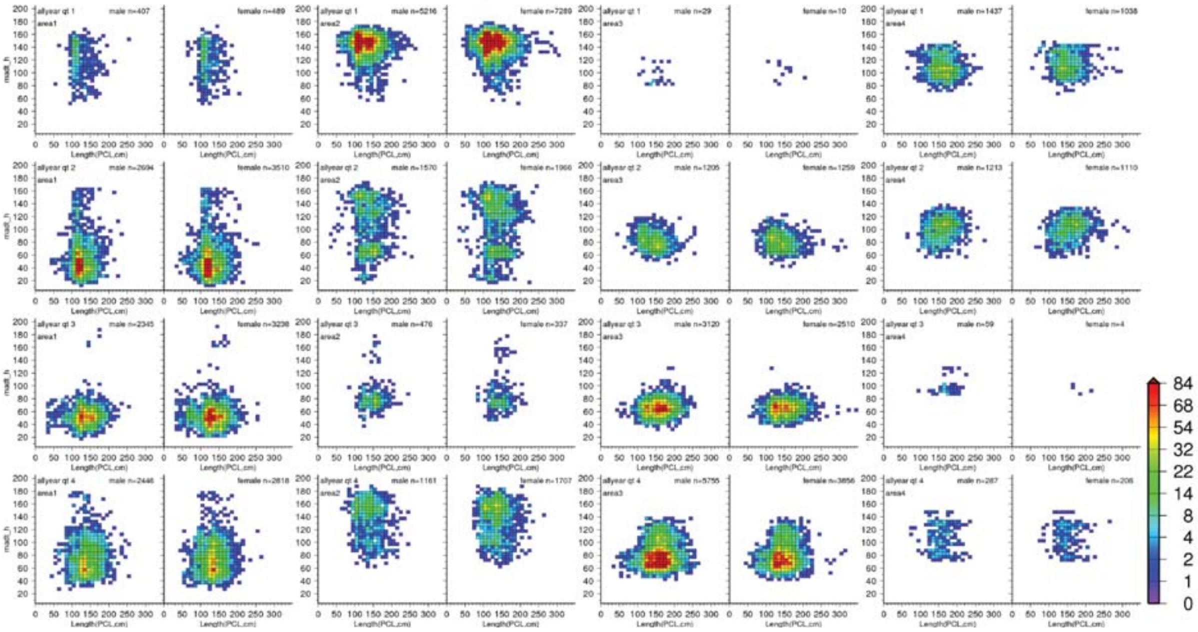

Figure 7. Quarterly relationship between size (X-axis) and SSH (Y-axis) by area and sex.

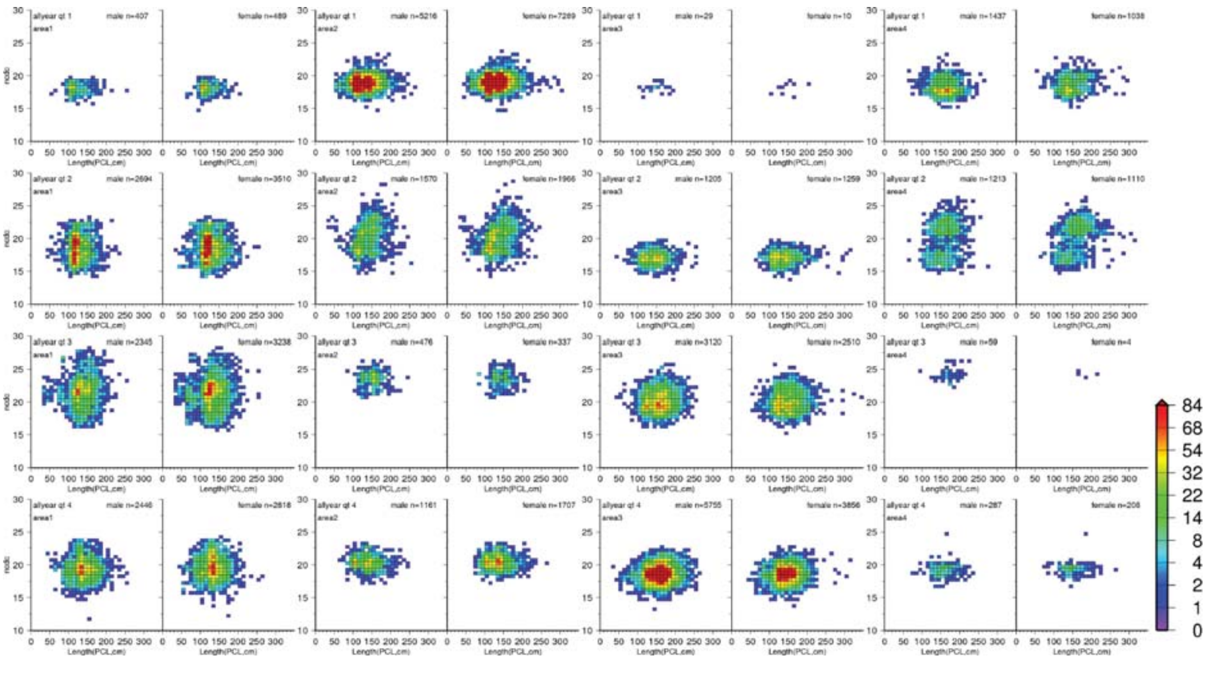

Figure 8. Quarterly relationship between size (X-axis) and SST (Y-axis) by area and sex.

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