AACL BIOFLUX

**Aquaculture, Aquarium, Conservation & Legislation
International Journal of the Bioflux Society**

Describing the shape of *Sardinella lemuru* from Sarangani Bay, Philippines using the landmark-based geometric morphometric analysis

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Abstract. This study used landmark-based geometric morphometric to find out and depict the body shape of *Sardinella lemuru* collected from Sarangani Bay in Mindanao, Philippines. A total of 60 fishes (30 males and 30 females) from the sampling site were digitized and landmarked using 18 landmarks. The body shape variation was obtained and synopsized by the boxplots of the relative warp (RW) scores along with the extremely positive and the extremely negative warps. Important results were accentuated with discriminant function analysis (DFA) having the result of p=0.1651. Overfishing activities of large scale fishing industries pose a big threat to the breeding season of the small pelagic fishes and its body shape is a great factor for their survival and ability to migrate. Thus, this study shows that landmark-based geometric morphometric methods is a successful tool in relating the shape of *S. lemuru* to the overfishing activities.

Key Words: Tamban, relative warps, sexual dimorphism, overfishing.

Intoduction. Philippine archipelago is considered as the richest spring of aquatic resources in our planet (Allen 2007, as cited by Luceno et al 2013). Marine fishes, sea grasses and marine invertebrates are widely scattered across the archipelago. Filipinos rely on marine fish for approximately 50% of their protein, and this reliance could reach up to 80%, particularly in municipal coastal areas (Savina & White 1986 as cited by Metillo & Aspiras-Eya 2014).

One of the most significant pelagic fishes in the Philippines in terms of its commercial aspect is the sardines. They belong to the Family Clupeidae, Subfamily Clupeinae. They usually possess a constricted, silvery, streamlined body, projecting scales and a single soft-rayed dorsal fin (Luceno et al 2013). Filipinos commonly called it "Tamban". Ecologically, sardines are located at the bottom of the food web that is consumed by pelagic tuna and mackerel, as well as plentiful sea birds and marine mammals. Regardless of its economic and ecological importance, only few studies have been conducted that highlights its body description and its diversity.

Sardinella lemuru is a well known species spread in eastern Indian Ocean including southern coasts of East Java, Bali and Lombok (Mahrus et al 2012). It forms the dominant part of small pelagic fisheries production in the Philippines (De Guzman et al 2012). Sardines in the Philippines form shoals in coastal waters over the continental shelf where depth is less than 200 meters (Luceno et al 2014). Additionally, *S. lemuru* is not just consumed as fresh fish, it is also processed for fishmeal, canning and dried for consumption. Despite the abundance of aquatic resources, the over fishing activities have always been a threat and factor of decreasing the populations of pelagic fishes, including *S. lemuru.*

Over fishing activity is an unstable and non-sustainable use of the ocean. Fishing too much leads to the degradation of the fish population. In the Philippines, during the months of November until March is the spawning period for the *S. lemuru*. This period will allow the fishes to spawn and grow their population, but the over fishing activities of large scale fishing industries pose a big threat to the breeding season of the small pelagic fishes.

The Geometric Morphometrics (GM) is a new method in describing the shape of a specific specimen using its landmark configurations. This method is considered as one of the most reliable techniques in the field of morphology. It provides precise statistical analysis of the shape, size, form, and symmetry because of the preservation of its actual shape. GM method is also suitable for the graphic appearance of results for visual demonstration and contrast of shape changes based on measured distances, angles, and ratios (Luceno et al 2014).

The body shape of the pelagic fishes is a great factor for their survival and ability to migrate. This study aims to relate the body shape of *S. lemuru* to its survival and the threats of overfishing activities. The information gathered in this study will be useful to the fishing industry since there are only few studies which have been conducted highlighting the body description of *S. lemuru* and the threats of overexploitation.

Material and Method

Study area. The research was conducted on September 3–4, 2015 at Sarangani Bay, Sarangani Province, located on the southern tip of Mindanao in the Philippines (Figure 1). It opens up to the Celebes Sea on the Pacific Ocean. Having the landmark of 5^{o}58’0”N, 125^{o}11’0”E. General Santos City, one of the Philippines most important cities and ports, is located at the head of the bay, making the bay one of the busiest and often the sight of shipping accidents.

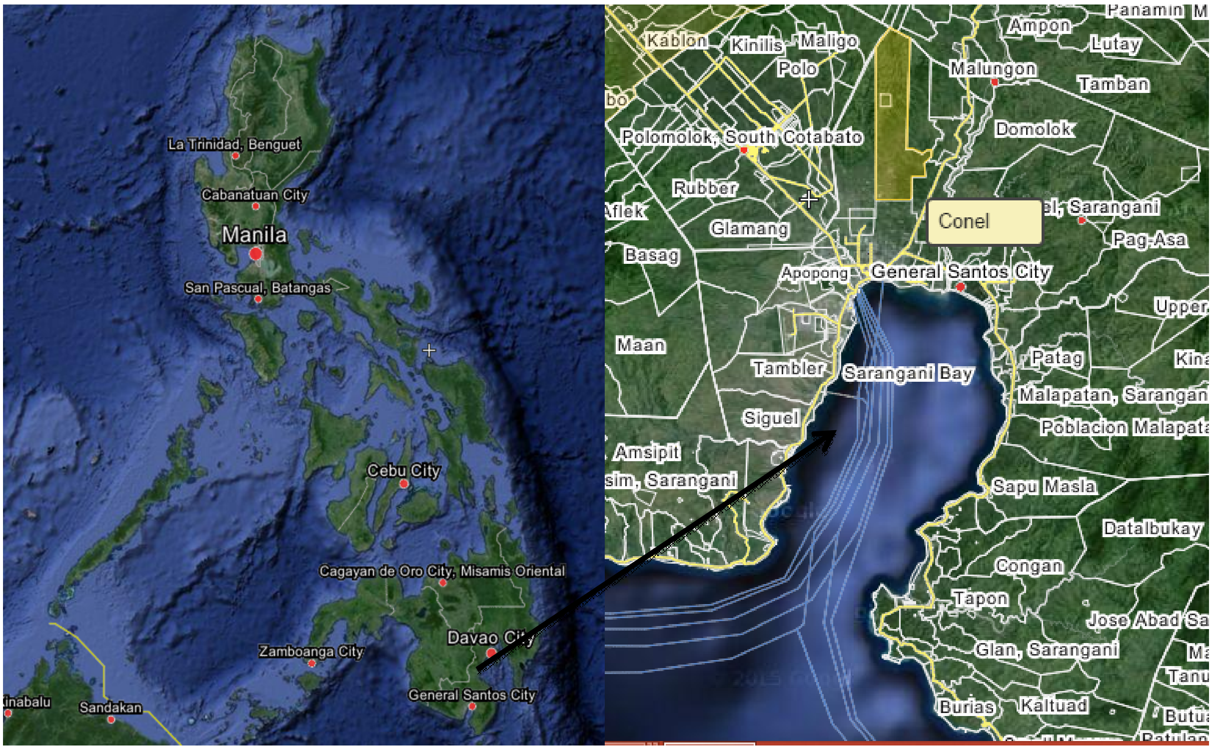

Figure 1. Map showing the study area (Source: Wikimapia).

Fish specimen. *S. lemuru* samples (Figure 2) were collected from the bay of Sarangani; there were 100 specimens obtained from the site. We immediately put the fish in an icebox to preserve it and to maintain its freshness for the image acquisition. Sex of the samples was determined through its gonads. A 16MP Digital Camera (Canon model

A2300 HD) was used in capturing the image of the specimens. The samples were placed in Styrofoam with fins spread so as to show their whole shape. Only the unsullied and fresh specimens were included (30 males and 30 females). The damaged fishes were rejected.

Figure 2. Fish specimen.

Landmark selection and digitization. Geometric morphometric is a fixed and detailed examination of shape change and variation through the homologous points or anatomical landmarks. The body shape was determined by the use of free ware facilities TpsDig version 2.12. The 18 landmarks was established and Figure 3 shows the land points: 1) anterior tip of snout at upper jaw, 2) most posterior aspect of neurocranium (beginning of scales nape), 3) origin of dorsal fin, 4) insertion of dorsal fin, 5) anterior attachment of dorsal membrane from caudal fin, 6) posterior end of vertebrae column, 7) anterior attachment of ventral membrane from caudal fin, 8) insertion of anal fin, 9) origin of anal fin, 10) insertion of pelvic fin, 11) origin of pectoral fin, 12–16) contour of the gill cover, 17) posterior portion of maxillary, 18) center of the eye.

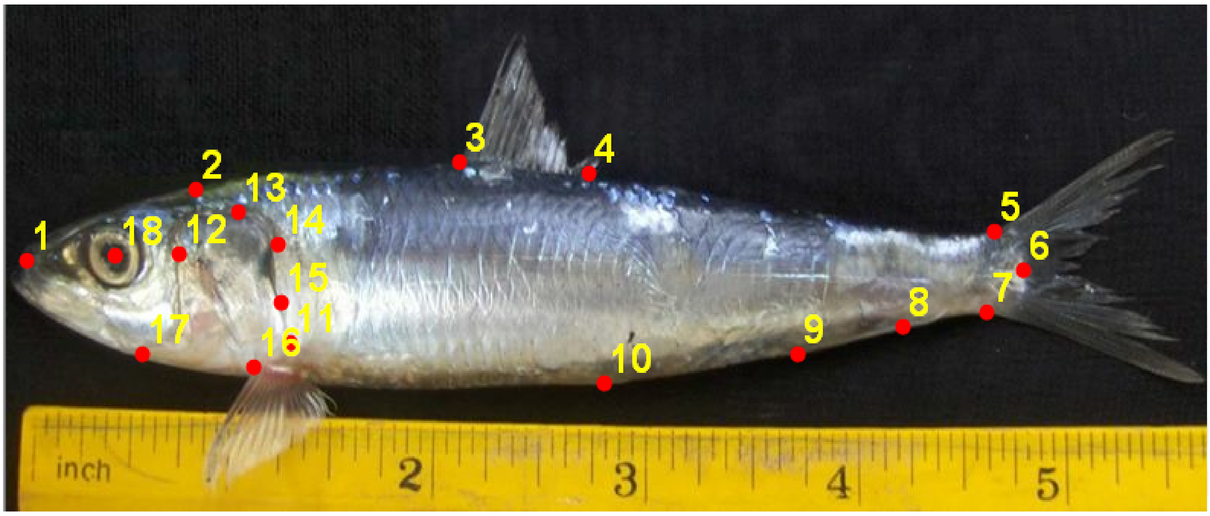

Figure 3. Locations of the 18 landmarks for analysing fish body shape.

Shape analysis. There are two variables, the x (positive warp) and y (negative warp) coordinates of the body shapes of the fish and transformed into shape variables preceding to the statistical analyses of shape variation by the use of Tps Relwarp (RW) by the two sexes. The Discriminant Function Analysis (DFA) was used to evaluate the differences of male and female of *S. lemuru,* according to the method of Hammer et al (2001).

Results and Discussion. As mentioned before, thirty (30) males and thirty females of the *S. lemuru* from the sampling area were explored to geometric morphometric analysis in order to verify the body shape variation that exists due to the effects of overexploitation. Overfishing is most prevalent in small pelagic fishes such as *S. lemuru* because they are concentrated into the shallow areas of the sea where they can be easily captured. Small pelagic fishes lack the necessary body-shape for them to be able to migrate. The body shape variation and its outline is presented and synopsized by the boxplots of the relative warp scores along with the extremely positive and the extremely negative warps. The uppermost part for every image shows the body shape of the species (Figure 4a and b). Table 1 abridges these variations in both of the male and female populations from Sarangani Bay.

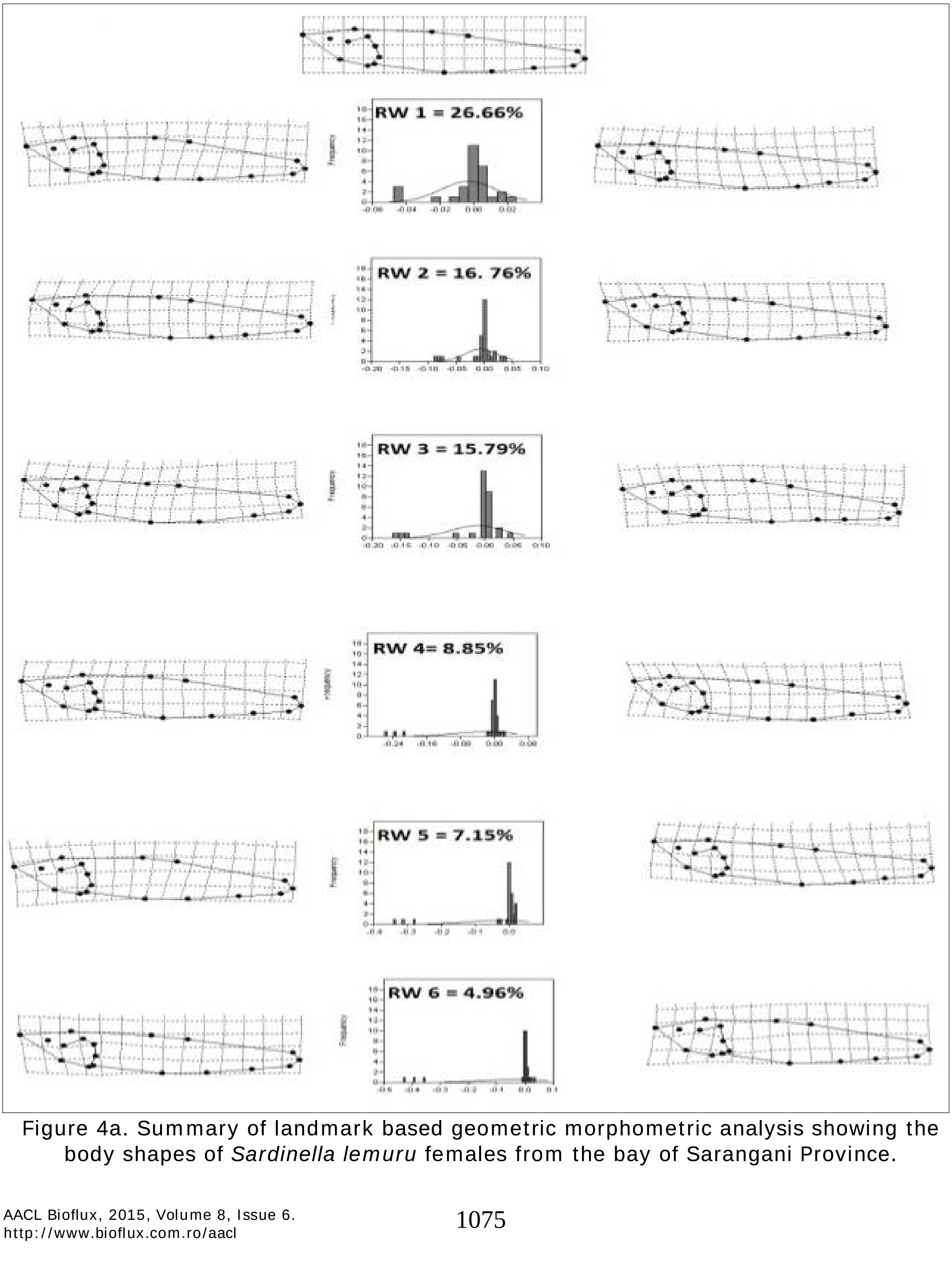

Figure 4a. Summary of landmark based geometric morphometric analysis showing the body shapes of *Sardinella lemuru* females from the bay of Sarangani Province.

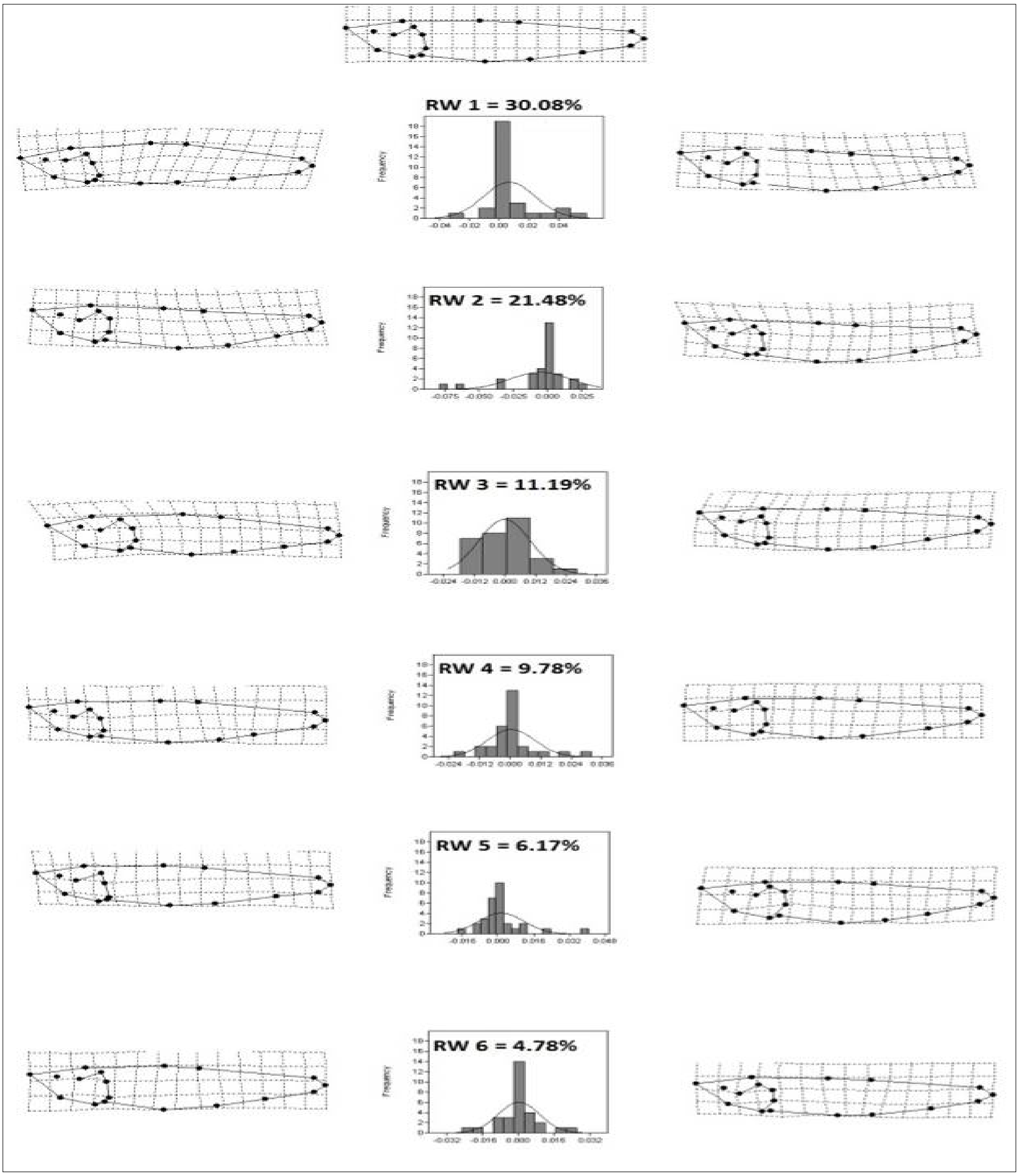

Figure 4b. Summary of landmark based geometric morphometric analysis showing the body shapes of *Sardinella lemuru* males from the bay of Sarangani Province.

Table 1

Variation in the body shapes of *Sardinella lemuru* populations as explained by each of the significant relative warp and its corresponding percentage variance

	Variation	Male	Variation	Female
RW1	30.08%	Variation on the twist of the fish's body. The extremely positive warp shows an upwardly curved body, just like a letter U. As it moves towards in the middle, the body twist at a descending manner, like a reversed U as differed to the extremely positive warp.	26.66%	Variation in the twist of the fish body. The extremely positive warp bend upward as it gets further away from the middle making the dorsal side of the fish look arched of the fish body shape while at the negative extreme, it bends at a descending manner creating the ventral side of the fish appear arched aloft somewhat like an reversed U.
RW2	21.48%	Variation in the firmness of the body of the fish at the mid-section. Extremely positive warp demonstrate a compacted mean brought about by the apparent prognosis of the portion near the belly, and as it extends the extremely negative side of the warp, the mid-section of the fish body somewhat compacted middle showing a non-sharp features	16.76%	Variation in the firmness of the body of the fish at the mid-section. Extremely positive warp demonstrate a compacted mean brought about by the apparent prognosis of the portion near the belly, and as it extends the extremely negative side of the warp, the mid-section of the fish body somewhat compacted middle showing a non-sharp features
RW3	11.19%	Variation in the disparity in length of the dorsal and the ventral side of the body of the fish. Extremely positive warp shows a extended ventral side whereas dorsal side is dumpier. Extremely negative warp, on the other part appears a vice versa size in dorsal and ventral side.	15.79%	Variation in the disparity in length of the dorsal and the ventral side of the body of the fish. Extremely positive warp shows a extended ventral side whereas dorsal side is dumpier. Extremely negative warp, on the other part appears a vice versa size in dorsal and ventral side.
RW4	9.78%	Variation in the part of the pelvic fin area of the fish body. Extremely positive warp displays enlarged zone in the pelvis while the extremely negative warp displays a compacted pelvic zone.	8.85%	Variation in the belly section. Extremely positive warp shows an extended section between the inclusion of the pectoral fin to the inclusion of the pelvic fin. This slowly decreases as it moves toward the negative extreme warp.
RW5	6.17%	Variation in the measurement of the dorsal fin from its origin to the insertion. Extremely positive warp shows a dorsal fin that is dimunitive and as the relative warp advances the mid-section towards the negative extreme, and its increase size.	7.15%	Variation in terms of the measurement from the most posterior property of the neurocranium to the origin of dorsal fin. In extremely positive warp, the length expanded as it looms the middle zone and towards the extremely negative warp which has the extended measurement of this particular region of the fish.
RW6	4.78%	Variation on the region starting from the posterior part of the neurocranium to the attachment of the dorsal fin. The extremely positive warp indicates a condensed area within this part while the extremely negative warp shows a wide-ranging area.	4.96%	Variation on the region starting from the posterior part of the neurocranium to the attachment of the dorsal fin. The extremely positive warp indicates a condensed area within this part while the extremely negative warp shows a wide-ranging area.

The RW of the *S. lemuru* showed differences between the female and male. The total variations for male was 83.48 while 80.17% for the female. Both male and female show upwardly curved but differ as it goes in the middle. The female shows a descending manner in negative warp just like a reversed letter U. The male and female in the positive warp show compacted belly in mid-section but they differ in negative warp for the female, which shows much broader area in the body. The male extends the ventral side in extremely positive warp and the dorsal side was dumpier. However the female shows more extended ventral side but became slighter in negative warp and its dorsal became lengthier. The variations of male and female in fin are different for the male in the positive warp shows enlargement in pelvis but compacted in negative warp. While the female shows extended section between the inclusion of the pectoral fin to the inclusion of the pelvic but decreases as it moves to the negative warp. In the measurement of dorsal fin from its origin to the intersection, the male in the positive warp shows a very small dorsal fin but increases as it goes to the negative warp. While the female shows more expanded dorsal fin as it goes to the mid-section and towards the negative warp. The measurement from the posterior part of the neurocranium to the attachment of the dorsal fin of both male and female shows a condensed area within the part in the positive warp while shows a wide-ranging area in the negative warp.

Figure 5 shows the significant difference of the two sexes between their shape variation and the result of p = 0.1651 this state that the fish are actually the same through its variation. The used of DFA further highlights the minimal overlap of some of the morphological contribution.

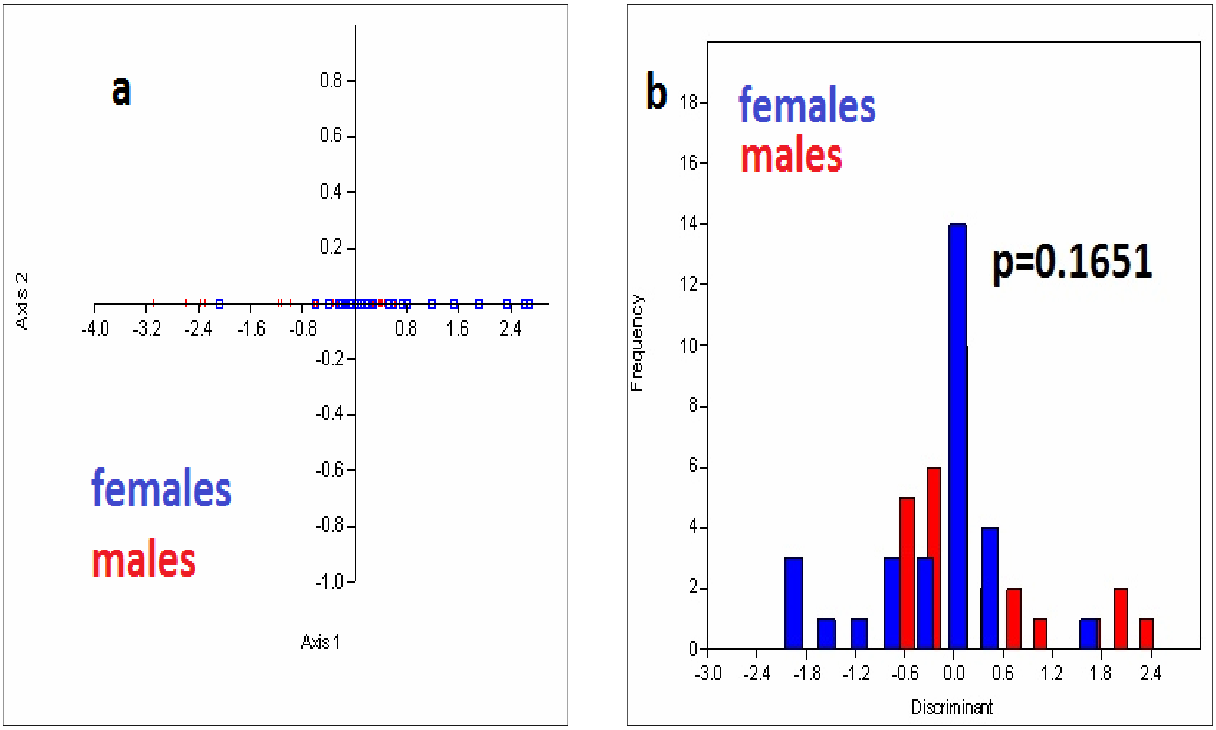

Figure 5. Discriminant Function Analysis (DFA) plots of the relative scores of *Sardinella lemuru* populations from Sarangani Bay.

It can be simplified that the variations arising in this species are mainly on the twist of the body, firmness and looseness at the mean of the body particularly in the belly area, the measurement of the dorsal side relative to the ventral side and vice versa, the length between the insertion of the pectoral fin to the insertion of the pelvic fin and also in the region between the posterior most aspect of the neurocranium to the origin of the dorsal fin. A slender variation can also be viewed at the snout/gape region of the fish. It can be viewed that the females exhibit variations that are geared towards body shape that are skilled of supporting massive number of eggs (as justified by the more enlarged belly region linked to the males) while the males exhibit a less belly and a more trim body outline. In addition, males are generally slight shorter or almost the same length females.

As we can see, we can determine a little difference from the two sexes that we have evaluated due to the overexploitation in the Sarangani Bay. It affects the variation of the body shape of the two sexes that made them nearly or approximately the same. That they only differ in their neurocranium, pelvic part and belly section.

According to Gaughan & Mitchell (2000), in *S. lemuru* found in the midwest coast of Western Australia males and females proportion remained generally constant throughout their sampling period. The total fish examined in the study, the ratio's result was 1:1 where 0.49 in females and 0.51 in males, this is the size classes found in the sex ratio. For the < 140 mm size class a ratio of 1.7:1 females to males was found. For the > 170 mm size class there was also a tendency for greater numbers of females to males.

According to Mahrus et al (2012), the morphometric characteristics of the *S. lemuru* from the Lombok Strait was 22 cm in length, its body was a shape of cylinder with the width less than 30% of the standard length; one unbranched and 7 branched to the total number of 8 pelvic rays. These characteristics were showed consistently to their previous study. However the *S. lemuru* in Lombok Strait have differences in size from the other places particularly in Sibolga Bay, Indonesia, Mediterranean and Celtic Sea and from Northeastern Atlantic and Western Mediterranean.

Thomas et al (2014) studied *Sardinella gibbosa* from different 8 locations across the Philippine archipelago and explained that the similar group due to head shape variations have characterized the sub-species within the sardine, which after confirmed this through the molecular evidence from mitochondrial data. They claimed that the morphological differences between the closely related sardines are often characterized by a little difference in measurements or in meristic counts. For example, the *Sardinella tawilis* and *Sardinella hualiensis* are both related sardines, and excluding their habitat they only differ a little in head length and gillraker count.

According to Luceño et al (2013) females of *Sardinella fimbriata* in Butuan City showed a more curvature variation in the body compared to the males but the male however showed greater variation in the distension in the mid section of the body. The female show much variation in the length of the area between the origin of anal fin and insertion of pelvic fin. Also the females dorsal fin is longer than the males.

According to (Luceño et al 2014), the males of *S. lemuru* in Dipolog City showed greater variation in the curvature of the body but less in the mid section of the body. However the females showed more length dorsal fin just like the females found in Butuan City. While in the Pagadian City, the females showed the greater variation in the curvature of the body and the mid section of the body. The males had longer dorsal fin.

Tsikliras & Antonopoulou (2006) studied another species of sardine which is the *Sardinella aurita* also known as the round sardine. It was collected in the North eastern Mediterranean Sea. The study showed that the specific size sex–ratio claimed that the number of males and females was equal in lengths lower that 160 mm but the number of males was higher for length classes of 160 and 170mm. At maturity, males in the northern Aegean Sea were smaller and younger at maturity than females.

Conclusions. Morphometric studies can provide useful information on the evolution of fishes. Through the use of statistical tools and analysis of the data, we found out that *S. lemuru* is incapable of migrating into the deeper portion of the sea. *S. lemuru* body shape is a relevant factor in determining its locomotion capacity which resolute that small pelagic fishes tend to be concentrated to the areas where they can be easily caught.

Thus, this study suggests that overfishing is most prevalent in small pelagic fishes such as *S. lemuru* because they are concentrated into the shallow areas of the sea where they can be easily captured. Small pelagic fishes lack the necessary body-shape for them to be able to migrate.

Acknowledgements. The researchers are deeply grateful to the Mindanao State University- Gen. Santos City for the support upon conducting this study. They also thank Prof. ElaniRequieron, together with her mentor Prof. Mark Anthony J. Torres for the supervision and guidance in utilizing the softwares for geometric morphometric analysis.

The families and friends of the researchers for their financial and moral support were also recognized.

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Received: 01 December 2015. Accepted: 27 December 2015. Published online: 29 December 2015.
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How to cite this article:
Giducos C. S. Karim S. I., Diamalon A. L., Piang M. M., Torres M. A. J., Requieron E. A., 2015 Describing the shape of *Sardinella lemuru* from Sarangani Bay, Philippines using the landmark-based geometric morphometric analysis. AACL Bioflux 8(6):1072-1080.