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Abstract

Sardines (Clupeidae) make up a substantial proportion of the fish catch across the Philippines and consequently are the most accessible source of animal protein for millions of Filipinos. Further, this fishery is an economic engine providing thousands of jobs and generating revenue at the individual, municipal, and national levels. Ecologically, sardines are basally positioned in a food web that supports pelagic tuna and mackerel, as well as numerous sea birds and marine mammals. Philippine sardine biodiversity is among the highest in the world and includes the only known freshwater sardine species. The ecological and economic value of sardines alone warrant further research; however the looming effects of global climate change and an ever-growing population in the Philippines increase the urgency of this research. Signs of a collapsing sardine stock, reported earlier this decade, have promoted investigations of their abundance, viability, and long-term integrity as a fishery. Furthermore, the historical collapse of small pelagic fisheries elsewhere in the world may serve as guides in mitigating a similar fate in the Philippines. Our goals here are to a) review the current understanding of sardines in the Philippines; b) provide a snapshot of their status using the most recent data available; and c) highlight where the greatest concerns are and how new research may aid in creating a sustainable and secure sardine fishery.

Introduction

The Philippines has been acknowledged as the center of marine biodiversity on the planet (Carpenter and Springer 2004) and this has been confirmed by various reports on marine fishes (Allen 2007), corals (Veron *et al.* 2009), seagrasses (Short *et al.* 2007), and marine invertebrates (Wells 2002). It is part of the region referred to as the Coral Triangle that, along with the waters surrounding Indonesia, Malaysia, Brunei, Timor L'Este, Papua New Guinea and the Solomon Islands, an area that contains 76% of the total coral biodiversity and 37% of reef fish biodiversity in the world (Allen 2007, Veron *et al*. 2009). However, due to numerous and extreme anthropogenic pressures, the country is considered also as one of the hottest hotspots in world in terms of biodiversity conservation (Roberts *et al*., 2002).

Numerous hypotheses have been proposed to explain this phenomenon of marine biodiversity richness. These include the role of the complex geologic and oceanographic history of the region (Hoeksema 2007), the array of variable influential features including: land-derived nutrients (Cordero *et al*. 2003), seasonal & regional upwelling (Udarbe-Walker and Villanoy 2001), El Nino Southern Oscillation (ENSO) events (An and Wang 2000), and even overfishing among others.

Expectedly, fish diversity in the Philippines is also very high with over 2,500 species reported to be present thus far. Among the fish species, small pelagics have historically dominated the fishery in terms of volume of landings. It comprises about 60% of the total capture fishery production of the country as of 2003 (FAO, 2010) and is estimated to have a Maximum Sustainable Yield (MSY) of 550,000 metric tons (Dalzell *et al*. 1987). Unfortunately, catch per unit of effort (CPUE) for small pelagic fisheries began to decline in 1956 and have experienced a relentless decline since (Barut *et al*. 2003).

Within the small pelagic fishery, sardines are one of the most commercially important. For example, two sardines, Fimbriated sardine (*Sardinella fimbriata)* and the Bali sardine (*S. lemuru)* accounted for a combined 331,298 metric tons, valued at approximately USD 146,300,000 (PHP 8.06 billion) (at 2005 exchange rate value), based on 2005 Bureau of Agricultural Statistics (BAS) data. In this review, we present the current status of sardines in the Philippines, its biology and ecology, as well as highlight some issues that need attention to sustainably manage the resource.

Taxonomy and Diversity

Taxonomy

Sardines are taxonomically placed within Phylum Chordata (vertebrates), Class Antinopterygii (ray-finned fish), Order Clupeiformes, and Family Clupeidae. Five sub-families are contained in Clupeidae with the scope of this paper focusing on the largest of the subfamilies, Clupeinae, herein referred to as "sardines". There are seventy-two species under the Subfamily Clupeinae.

Sardines are distinguishable from other small pelagics through their rounded upper lip and two pronounced supra--maxilla at the proximal end of the mouth (Whitehead 1985). The members of the subfamily are generally classified from each other using body depth and standard length, presence or absence of colored spots, colored lines, and fleshy outgrowths behind the gill cover (Figure 1). In addition, the positions of the fins (dorsal, anal and pelvic), the number and characteristics of the fin rays (pelvic and anal) , body dimensions, fin features e.g. whether or not striae are continuous or discontinuous across the center of the scales, the number of scutes on the belly (from 28-34) and the number of gill rakers (from 26 to 253) on the lower half of the first gill arc are essential in differentiating between similar sardine species (Whitehead 1985).

In the Philippines, there is inconsistency in the published literature on the exact number of sardine species occurring in the country. Herre (1953) listed nine species of sardines (*Sardinella aurita*, *S. brachysoma*, *S. fimbriata*, *S. gibbosa, S. longiceps, S. melanura, S. samarensis, S. sindensis* and *S. sirm*). Whitehead (1985) reported nine species while another five species occur in the adjacent water bodies, i.e. Sulawesi Sea and South China Sea (Table 1). Conlu (1986) reported seven species (*S. brachysoma*, *S. fimbriata*, *S. longiceps*, *S. melanura*, *S. samarensis*, *S. sindensis*, and *Sardinops sagax*). Only one species (*S. fimbriata*) is corroborated across the three reports whereas other inclusions do not have ranges that extend to the Philippines or are found in other oceans exclusively. Sardines have many local names including *manamsi*, *lao-lao*, *tunsoy*, *turay*, *tamban*, *tabagak*, etc.,Table 1 (Ganaden and Lavapie-Gonzales 1999).

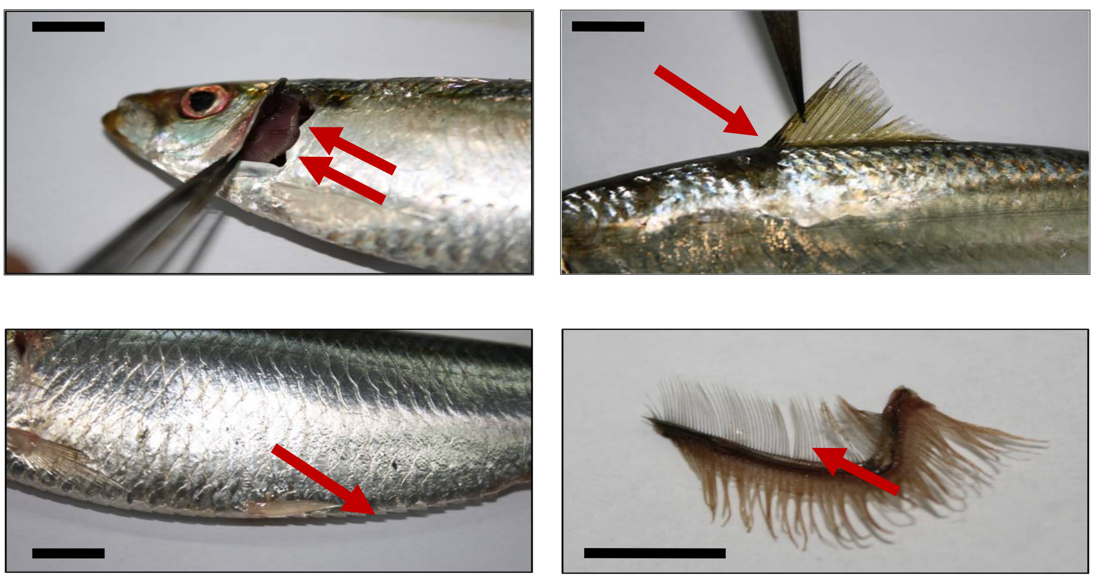

Figure 1. Photograph plate of sardine morphometric and meristic features for accurate species identification. Clockwise from top left – arrows indicating fleshy outgrowths behind operculum, black spot at dorsal fin origin, ventral scutes, and lower gill rakers (gill arc removed from fish). Black scale bar = ~ 1cm.

Table 1. List of Clupeidae of the Philippines and other species of interest. Includes scientific name, common name in English and Tagalog (Ganaden and Lavapie-Gonzales 1999), standard length, if the species a targeted fishery in the Philippines, and if the species is found in Philippine coastal waters.

Name	Common Name	Name in Tagalog	Standard Length	Philippine Target Fishery	Present in Philippine coastal waters
Amblygaster sirm	Spotted sardinella	Tamban	20 cm	Yes	Yes
Escualosa thoracata	White sardine	-	8 cm	Yes	Yes
Herklotsichthys dipilonotus	Blacksaddle herring	Dilat	7 cm	Artisanal only	Yes
Herklotsichthys quadrimaculatus	Bluestripe herring	Dilat	10 cm	Artisanal only	Yes
Sardinella albella	White sardinella	Tunsoy	10 cm	Yes	Yes
Sardinella fimbriata	Fringescale sardinella	Tunsoy	11 cm	Yes	Yes
Sardinella gibbosa	Goldstrip sardinella	Tunsoy	15 cm	Yes	Yes
Sardinella lemuru	Bali sardinella	Tunsoy	20 cm	Yes	Yes
Sardinella tawilis	Freshwater sardine	Tawilis	10 cm	Yes	Yes

Sardinella tawilis is the only known freshwater sardine and is endemic to Taal Lake, Batangas, the third largest lake in the Philippines. It is believed that it has immigrated to Taal Lake from the South China Sea when it was formed by several eruptions 260 years ago (Hargrove 1991, Samonte 2000). The species was formerly named as *Harengula tawilis* (Herre 1927) which was later re-described in 1980 by Wongratana into *Sardinella tawilis* and listed as one of 18 species of *Sardinella* in the Indo-Pacific Region. In 1985, Whitehead listed it as one of the 21 species of *Sardinella* world-wide and considered *S. tawilis* as the only freshwater *Sardinella*. It is also one of the five commercially important species of *Sardinella*. Its body size is fairly slender with a maximum size of 15.2 cm total length (TL) and maximum weight 27.3g (Froese and Pauly 2010). Number of scutes range from 28 to 30, lower gill rakers of 61 to 74, a steel blue colored dorsum with silvery flanks, black caudal and dorsal fin tips (sometimes specked black) and a black spot at the origin of the dorsal fin (Whitehead 1985, Herre 1927). A thin, black line may be present at the upper margin of the pectoral fin. Its main diet is zooplankton (Papa *et al.* 2008) and spawns intermittently throughout the year with peak spawning months from March to May (Pagulayan 1999).

Habitat and Life History

Habitat

Sardines in the Philippines form shoals in coastal waters over the continental shelf where depth is less than 200 m (Figure 2). The sole exception is *Sardinella tawilis* that is confined and endemic to freshwater Taal Lake.

Sardines occur in high abundance across and beyond productive coastal areas or upwelling regions in the country. The strength of upwelling has been tied to recruitment weight where juvenile sardines obtain the greatest biomass in moderate upwelling conditions (Skogen 2005). Too weak of upwelling conditions provide a suboptimum food source whereas too strong of conditions promote the growth of plankton not fed on by sardines.

It has been observed that in areas in the Philippines where there is high landing of sardines, there is also a high rate of primary productivity suggesting that there are numerous suitable sardine-supporting habitats in the country. In the Visayas, chlorophyll concentrations, an indicator of primary productivity, were the highest of any Philippine basin measures by Cordero *et al*. (2003) which they attribute largely to mobilized nutrients from land (Figure 2). Likewise, moderately-elevated chlorophyll levels were reported offshore of northern Luzon, eastern Mindanao, and the Bicol Shelf where upwelling occurs (Udareb-Walker and Villanoy 2001, Cordero *et al.* 2003) (Figure 2). Upwelling, such as that along the Bicol Shelf, take place where strong winds blow along a coastline and push surface water offshore thus allowing cooler, nutrient-rich water to rise into the euphotic zone where it supports heightened levels of phytoplankton productivity that in turn feeds zooplankton; both of which sardines prey upon (Whitehead 1985). Another mechanism for upwelling off the northwest coast of Luzon and east of Mindanao is wind stress curl with the intensity of these upwelling zones tied to the alternating northeast and southwest monsoons (Udareb-Walker and Villanoy 2001). Furthermore, elevated chlorophyll concentrations were found in the center of the identified upwelling regions and corroborate suggestions of higher primary productivity than in surrounding waters (Udareb-Walker and Villanoy 2001).

Recruitment

Peak sardine productivity and spawning in the country often co-occur with the Southwest Monsoon winds in the latter half of the year (Dalzell *et al.* 1990, Sulu Sea Management Plan unpublished, Olano *et al*. 2009), although additional *Sardinella* spp. recruitment pulses have been reported between February and September in the Visayan Sea (Guanco *et al*. 2009). In Tawi-Tawi *S. fimbriata*, *S. lemuru*, and *S. albella* have shown two peak recruitment periods which is a common finding in the Philippines (Aripin and Showers 2000). Likewise, spawning and recruitment vary within a single species such as *S. lemuru* which has a peak spawning period from October to December in the Sulu Sea and Moro Gulf (BFAR Region IX staff, pers comm) yet spawns in December to January off of Bali, Indonesia and in May in the South China Sea (Whitehead 1985). Maturity is reached in two to three years for many Philippine sardine species (as little as one year for some *Sardinella* species (Nair 1959); however, heavy fishing pressure often leads to individuals being capture prior to maturation (Guanco *et al*. 2009).

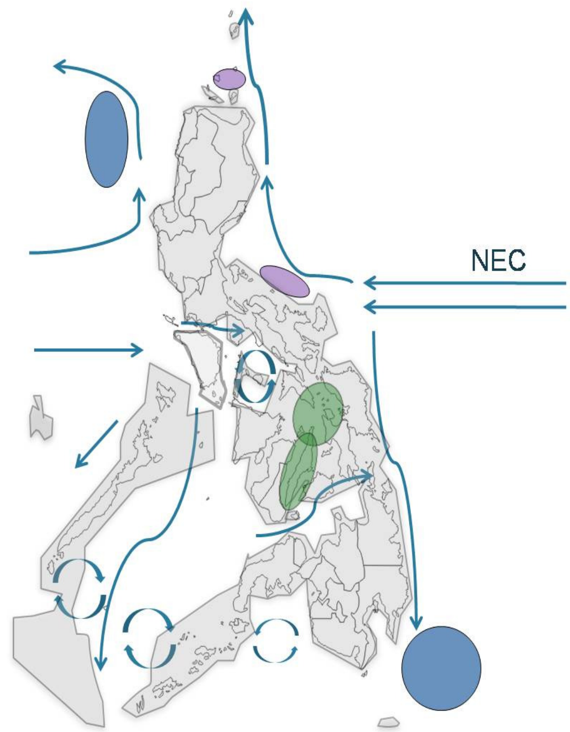

Figure 2. Map of the Philippine land mass outlined by shelf depth to 150 m (dark grey) and illustrating major ocean currents (arrows) during SW monsoon (Carpenter, unpublished data). Regions of off-shore upwelling near northwest Luzon coast and southeast Mindanao coast (light blue) (Udarbe-Walker and Villanoy 2001), upwelling near Batanes islands and Bicol (light purple) (Cordero *et al.* 2003), and area of high chlorophyll levels in Visayan Sea (light green) (Cordero *et al*. (2003).

Migration

Sardines are migratory, some species more strongly than others, but in the Philippines there has been little research into migratory routes and behaviors. Anecdotal accounts do provide some insight, such as the arrival of exceptionally high numbers of sardines within the Tanon Strait between Cebu and Negros Oriental in late 2009 to late 2010, although where the sardines arrived from is unknown (L. Arroyo, pers comm). Further anecdotal examples include an unpublished review by Bognot that cited evidence of sardines between the Visayan and Celebes Seas being a continuous, migrating population, and an unpublished version of the Sulu Sea Management Plan suggests *Sardinella* spp. in the Sulu Sea migrate between northwest Mindanao and the west side of the Sulu archipelago.

Distribution and Productivity

Bureau of Agricultural Statistics (BAS) Data

Based on BAS and FAO FIGUS database (2010), the distribution of *S. lemuru* and *Sardinella gibbosa* in the Philippines are depicted in Figures 3(a) and (b), respectively. The general distribution patterns of these sardine species are primary concentrated in the central Visayan water bodies, southeastern coasts of Luzon, and around the islands in Autonomous Region of Muslim Mindanao and Palawan, with a more patchy distribution in northern Luzon and southeastern Mindanao. These regions correspond to areas of shallow bathymetry and high primary productivity along the coastlines, but with little correspondence to the offshore upwelling near Mindanao and northwestern Luzon (Figure 2).

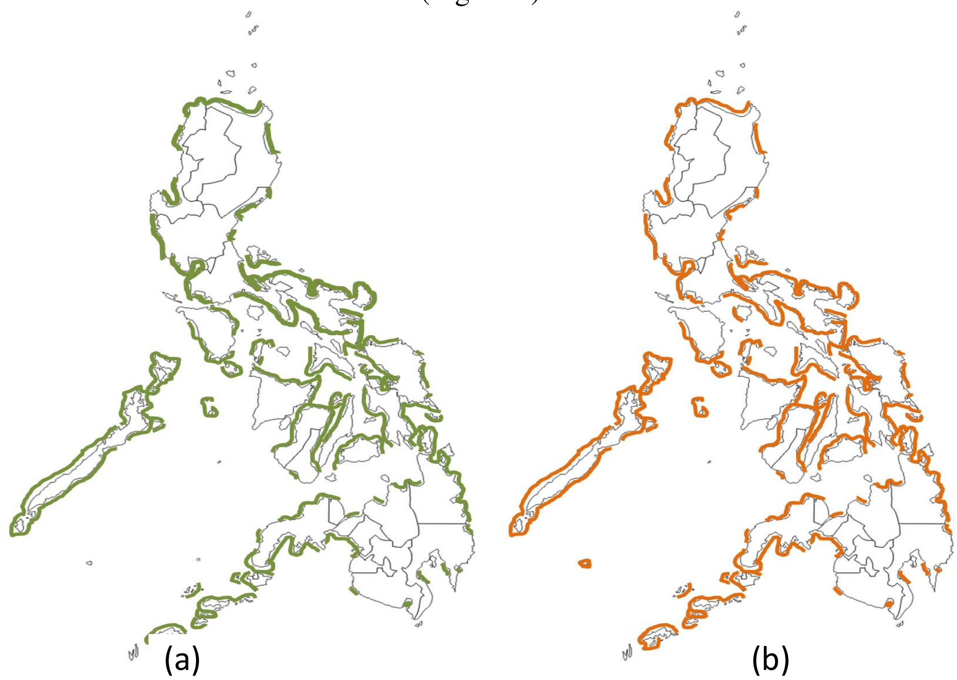

Figure 3. Distribution for *Sardinella lemuru* (a) and *Sardinella gibbosa* (b) in the Philippines (modified from FAO 2010).

The BAS has also released annual landing data from all regions for the 2004 to 2008 period, revealing that Region V produced the largest average annual *S. fimbriata* catch and Region I the smallest; whereas Region IX produced the largest average annual landing for *S. lemuru* (identified as *S. longiceps*) and Region III the smallest (Tables 2 and 3). In general, regions of the Visayas and the Zamboanga Peninsula (Region IX) produced proportionally more *S. fimbriata* than the rest of northern Luzon and southern Mindanao (Figure 5a). A similar pattern was observed for *S. lemuru*, with northern Luzon regions and southeastern Mindanao producing proportionally smaller catches than the Visayan Regions; however, the Zamboanga Peninsula was most productive, landing five times as many fish as any other region (Figure 5b).

Table 2. Annual landing (in metric tons) of *Sardinella fimbriata* for each region from 2004 to 2008 (from Bureau of Agriculture Statistics 2009).

Region	2004	2005	2006	2007	2008	Average (mt)
Region 1	109	175	246	182	207	**184**
Region 2	544	545	506	563	598	**551**
Region 3	761	999	1,068	1,116	1,272	**1,043**
NCR	116	662	1,625	641	364	**682**
Region 4a	561	1,301	1,101	2,865	5,258	**2,217**
Region 4b	8,501	8,807	13,229	12,339	9,362	**10,448**
Region 5	11,613	23,560	23,108	25,264	32,538	**23,217**
Region 6	12,341	12,052	12,374	16,403	16,655	**13,965**
Region 7	7,343	9,062	8,517	9,572	8,837	**8,666**
Region 8	3,327	3,780	5,127	7,203	7,371	**5,362**
Region 9	17,113	14,775	12,543	14,274	35,011	**18,743**
Region 10	543	557	805	1,279	1,294	**896**
Region 11	2,283	1,608	1,003	857	543	**1,259**
Region 12	731	1,679	943	546	203	**820**
Caraga	1,407	1,372	1,442	1,189	1,956	**1,473**
ARMM	2,716	3,234	5,528	6,116	6,418	**4,802**
TOTAL	**70,013**	**84,168**	**89,165**	**100,411**	**127,886**	

Table 3. Annual landing (in metric tons) of *Sardinella lemuru* (identified as *S. longiceps*) for each region from 2004 to 2008 (from Bureau of Agriculture Statistics 2009)

Region	2004	2005	2006	2007	2008	Average (mt)
Region 1	286	443	412	466	489	**419**
Region 2	1,127	1,217	1,100	1,258	835	**1,107**
Region 3	236	263	311	269	304	**277**
NCR	15,917	9,346	3,612	4,327	5,577	**7,756**
Region 4a	9,343	14,594	14,330	18,272	13,536	**14,015**
Region 4b	14,032	13,765	18,110	16,454	15,301	**15,532**
Region 5	6,077	7,236	8,519	11,478	12,995	**9,261**
Region 6	6,627	10,249	8,553	9,636	8,777	**8,768**
Region 7	4,893	4,818	3,788	2,830	3,942	**4,054**
Region 8	7,479	9,355	10,247	11,356	13,268	**10,341**
Region 9	100,335	145,115	112,058	98,517	126,257	**116,456**
Region 10	5,055	5,652	9,922	10,031	12,397	**8,611**
Region 11	5,215	6,753	3,477	5,089	4,022	**4,911**
Region 12	2,300	2,612	1,600	4,599	3,803	**2,983**
Caraga	2,110	3,494	3,865	3,695	4,810	**3,595**
ARMM	12,547	12,219	9,741	8,634	9,357	**10,500**
TOTAL	**193,578**	**247,130**	**209,645**	**206,911**	**235,670**	

National Stock Assessment Program (NSAP) Data

Data from the National Stock Assessment Program (NSAP) lead by the Bureau of Fisheries and Aquatic Resources (BFAR) for the annual landings of sardines by regions is currently being released by most regions. Mean annual landings from two or more years between 2004 and 2008 have been compiled and are illustrated in Figure 6a-d. Landing by species are variable across the twelve reporting regions with Region VI supporting the greatest annual landing for all presented *Sardinella* spp., whereas *Amblygaster sirm* had the greatest annual landing in Region IVb. Additionally, released data includes a number of sardine species that are not described as occurring in Philippine waters based on native ranges (Froese and Pauly, 2010) and (Whitehead 1985). These species include *Amblygaster leiogaster*, *A. clupeoides*, *Herklotsichtys blackburni*, *Sardinella brachysoma*, *S. fijiense*, and *S. melanura*, with the highest annual landing data (2338.7 mt) for any species being *S. melanura* in Region 7; a species whose range includes India and Indonesia south of Sulawesi, but does not include any part of the Philippines (Figure 7). This result may warrant a modification to the range of *S. melanura*, or this may be an identification issue as *S. melanura* is somewhat morphologically similar to *S. fimbriata* (Whitehead 1985).

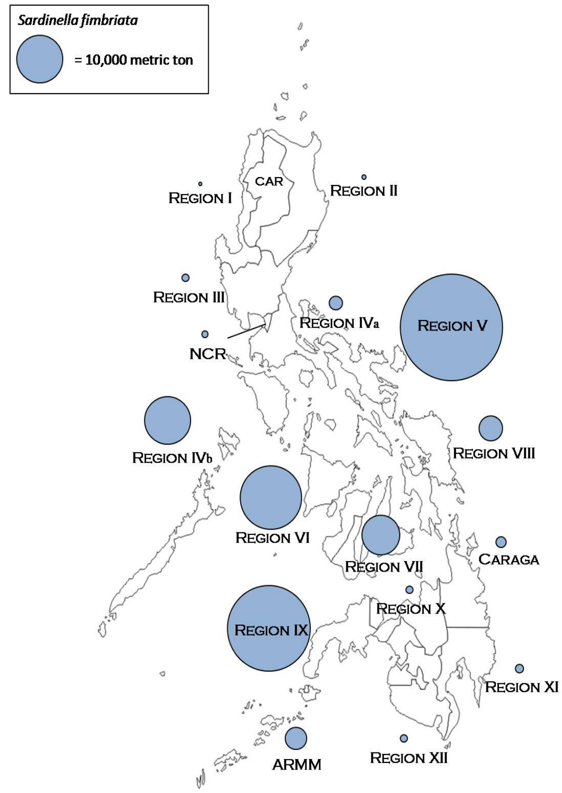

Figure 5. Bureau of Agricultural Statistics fisheries annual landing data from 2004 to 2008 (metric ton) by region b) *Sardinella lemuru* (cited by BAS as S. longiceps).

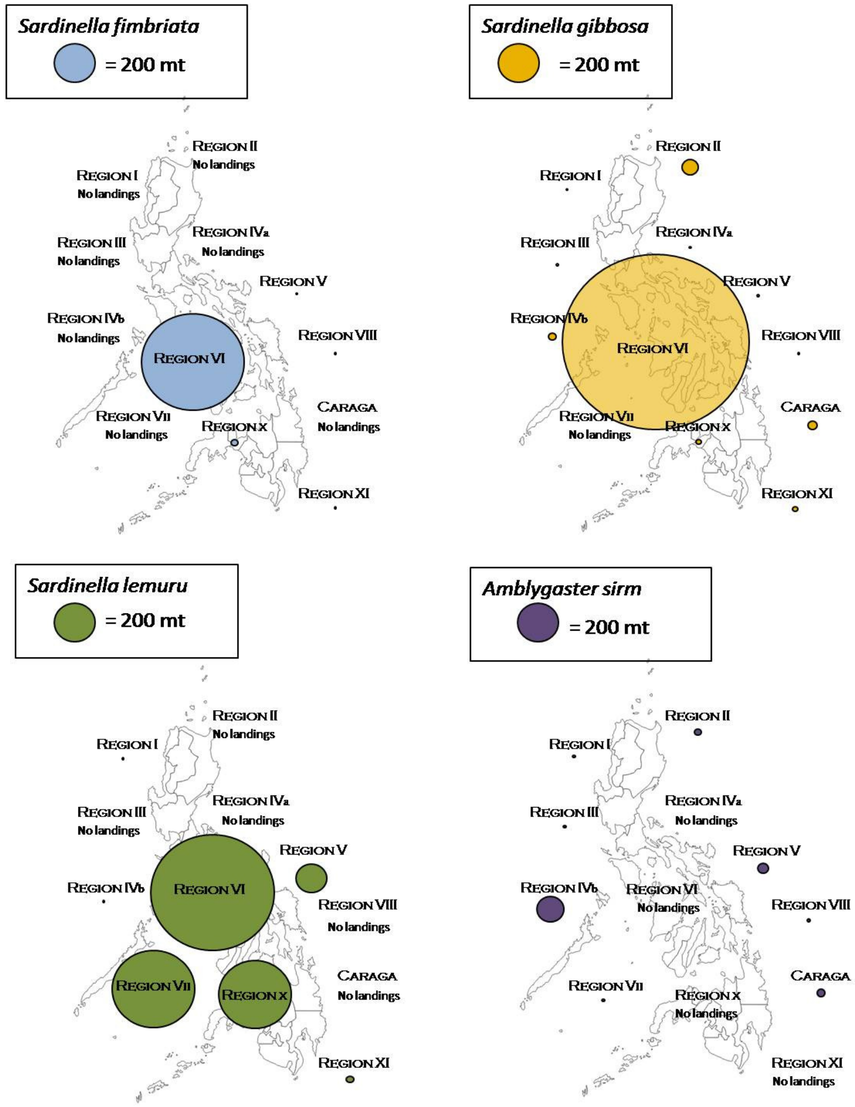

Figure 6. NFRDI National Stock Assessment Program (NSAP) annual fish landings (metric tons) from twelve regions from two or more years between 2004 and 2008 for a)*Sardinella fimbriata*, b) *Sardinella gibbosa,* c) *Sardinella lemuru*, and d) *Amblygaster sirm.*

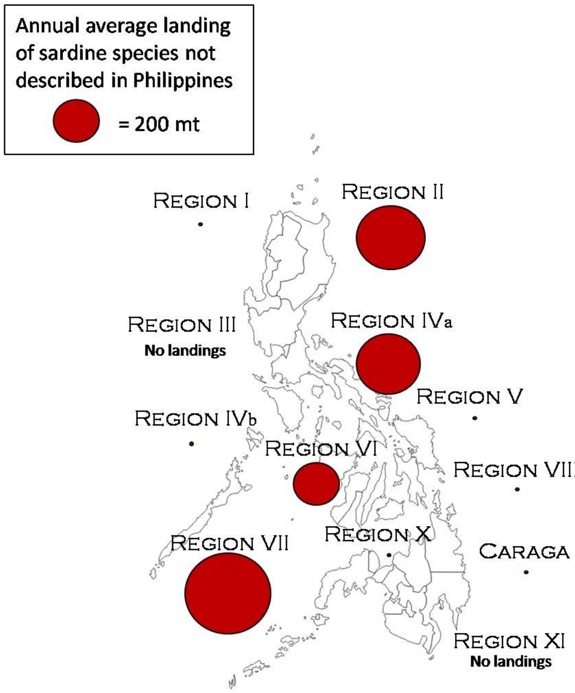

Figure 7. NFRDI National Stock Assessment Program (NSAP) annual fish landings (metric tons) from twelve regions from two or more years between 2004 and 2008 for combined landing for cited other sardine species whose range does not include the Philippines. No landings for non-Philippine species reported from Region III and Region XI.

Stock status

The sardine stocks in the Philippines at the national level appear to be healthy, although certain fishing grounds have started showing signs of depletion. Based on data from the NSAP, sardines in the western and central Visayas have been reported to be under heavy fishing pressure in particular, with stocks of *S. gibbosa*, *S. fimbriata*, and *S. lemuru* (reported as *S. longiceps*) being over-exploited (Guanco *et al.* 2009). Evidence for over-exploitation is derived from standard length data of captured fish which is currently less than the standard length at first maturity for the above mentioned species. In Sorsogon Bay (Southeast Luzon), *Escualosa thoracata* (white sardine), which is the dominant species captured appears to be overfished, with a trend of decreasing catch size with increasing effort (Olano *et al.* 2009). For some species, such as *Amblygaster sirm* (spotted sardine), the level of exploitation is site specific. In Honda Bay, Palawan, *A. sirm* is currently considered over-exploited in that it is harvested above optimal levels (Ramos *et al.* 2009). Yet other sardine species in Palawan are not under the same pressure with captured fish reaching a standard length greater than that of first maturity.

Concerns and Future Studies

Species identification

Proper identification of a fish in the field is critical to science and management and that there is great value in obtaining voucher specimens to confirm identification in a controlled laboratory setting. Accurate identification is paramount in confirming the validity of biological and genetic studies, stock assessments, and genuinely knowing the composition of fish catches for management planning.

Sardines can be morphologically difficult to distinguish and mistaken identities are common. *Sardinella lemuru* (Bali sardinella) and *Sardinella longiceps* (Indian oil sardine) are interchangeably misidentified because similar standard length, body depth, number of pelvic fin-rays (8). At one time *S. lemuru* being used synonymously with *S. longiceps* by Folwer 1941, the two species can be distinguished by the number of gill rakers (*S. lemuru* – 77-188, *S. longiceps* – 150-253) and *S. lemuru*'s shorter head length (Whitehead 1985). In fact, a review of relevant literature shows that *S. longiceps* has been reported in the Philippines since at least 1953 (Herre 1953) and multiple times thereafter (Ingles and Pauly 1984, Conlu 1986, Dalzell *et al*. 1990, Ganaden and Lavapie-Gonzales 1999, Samonte *et al*. 2000, Samonte *et al*. 2009, BAS 2010). Based on meristic analysis and known distribution, i.e. the range limit of these two species being in the Andaman Sea (Thailand) with *S. longiceps* occurring westward and *S. lemuru* eastward (Froese and Pauly 2010), we strongly argue for changing the records and means of reporting in the Philippines of *S. longiceps* as *S. lemuru*.

Other *Sardinella* spp. are similarly morphologically troublesome, particularly when distinguishing between *S. gibbosa*, *S. fimbriata*, and *S. albella*. These three very common species all have blue-green dorsum coloration with silvery flanks, a black-spot at the origin of the dorsal fin, and roughly eight to eleven frontoparietal striae on the head. Examination under the microscope reveals all have non-continuous striae on their scales and that *S. gibbosa* (range 32-34) may have one to two more minute gill rakers than *S. albella* and *S. fimbriata* (range 29-33). All three species have yellowish dorsal and caudal fins but *S. gibbosa*'s are more dusky, *S. fimbriata*'s blackish, and *S. albella*'s pale yellow – features that can be subjective and overlooked in field evaluations. *Sardinella gibbosa* does have a distinct thin golden midlateral line and golden head; however, even this is variable and can fade after freezing.

Likewise, earlier sardine diversity manuscripts have been inconsistent in their reporting of species occurrences in the Philippines. In his 1953 paper, Herre included *Sardinella fimbriata, S. gibbosa, S. sirm* (later changed to *Amblygaster sirm*), as well as multiple species whose range is not known to extend to the Philippines. These species include *Sardinella brachysoma* (cited as a synonym of *S. albella*), *S. longiceps*, *S. melanura*, *S. samarensis*, *S. sindensis* and *S. aurita*, an Atlantic Ocean sardine that resembles *S. lemuru* which does occur in the Philippines but was not included in Herre's listing. Conlu (1986) composed a similar list including *S. brachysoma*, *S. fimbriata*, *S. longiceps*, *S. melanura*, *S. samarensis*, and *S. sindensis*, however, excluded *A. sirm*. Conlu does include the similar looking *Sardinops neopilchardus* (Australian pilchard) which resembles *A. sirm* in having a series of distinct colored spots running down the flank of the fish's body, yet lacks *A. sirm*'s descriptive two fleshy outgrowths behind the gill opening. Conlu (1986) exclude the commonly found *S. gibbosa* (see Table 2, NSAP data), but does include *S. sindensis* which resembles *S. gibbosa* yet has a range that is restricted west of India (Whitehead 1985). *Sardinella samarensis* included by both Herre (1953) and Conlu (1986) and described as endemic to the Philippines by Conlu but has been grouped with *S. lemuru* by Whitehead (1985) and Froese and Pauly (2010).

Species identification can be quite problematic in sardines, however, with a combination of genetic studies and careful documentation of morphological and meristic characteristics, it is possible to clearly determine the diversity of sardine species in the Philippines. With increasing fishing pressure and decreasing stocks of several species, it is increasingly important to be able to identify which species are being caught so that a more accurate fisheries management plan can be developed.

Production

A comparison between BFAR NSAP data and BAS data for the two sardine species *S. fimbriata* and *S. lemuru* shows distinct differences in distribution. In the NSAP data the greatest average annual landing of *S. fimbriata* (Figure 6a) was in Region VI at 1,197 mt, whereas the BAS data shows the greatest average annual landing *S. fimbriata* in Region V at 23,217mt annually. NSAP data reported only 0.3 mt annually for *S. fimbriata*, whereas BAS reported 13,965 mt in Region VI. This is a considerable difference between the Regions and reporting groups. Likewise, NSAP reports Region VI also having the greatest average annual landing of *S. lemuru* at 1,608 mt, whereas BAS reports the highest average annual landing in Region XII at 116,456 mt. Differences in sampling methods and efforts may explain some of the discrepancy between the data sets; however, formulating a consensus between the two would greatly aid in establishing a clear value for sardine production. Furthermore, corroboration with the detailed data sets maintained by the sardine canning industry should be undertaken to provide further consensus.

Additionally, limited data is available on catch values contrasted with other fisheries species from BAS data only. The sardine species *S. lemuru* and *S. fimbriata* were the 2nd and 6th most common commercially caught fish species by weight, respectively, and 8th and 3rd most common municipally caught fish species based on average annual data from 2004 to 2008 (Table 5).

Table 5a. Most commonly captured fish by annual weight (total metric tons) for Commercial fisheries (from Bureau of Agricultural Statistics 2009). Shaded rows are sardine species.

Rank	Species (common/local name)	2004	2005	2006	2007	2008	Average
1	*Decapterus macrosoma* Roundscad /Galonggong	230,278	214,963	186,450	244,671	212,100	217,693
2	*Sardinella longiceps* Indian sardine/Tamban	146,758	176,929	142,652	134,310	166,995	153,529
3	*Katsuwonus pelamis* Skipjack /Gulyasan	115,739	112,696	130,930	152,098	181,563	138,605
4	*Auxis thazard* Frigate Tuna/Tulingan	141,321	113,840	111,675	123,636	88,244	115,743
5	*Thunnus albacares* Yellowfin tuna/Tambakol	87,095	69,833	66,334	82,660	116,529	84,490
6	*Sardinella fimbriata* Fimbriated Sardines/Tunsoy	36,433	46,323	47,907	52,105	66,372	49,828

Table 5b. Most commonly captured fish by annual weight (total metric tons) for Municipal fisheries (from Bureau of Agricultural Statistics 2009). Shaded rows are sardine species

Rank	Species (Common/local name)	2004	2005	2006	2007	2008	Average
1	*Decapterus macrosoma*	63,598	65,813	73,608	75,544	82,039	72,120

	Roundscad/Galonggong						
2	*Auxis thazard* Frigate Tuna/Tulingan	66,787	60,120	63,673	67,836	68,097	65,302
3	*Sardinella longiceps* Indian sardine/Tamban	46,820	70,201	66,993	72,601	68,675	65,058
4	*Decapterus maruadsi* Big-eyed scad/Matangbaka	64,782	56,601	60,260	61,562	58,576	60,356
5	*Rastrelliger kanagurta* Indian mackerel (Alumahan)	44,868	46,333	52,290	51,847	52,380	49,544
6	*Thunnus albacares* Yellowfin tuna/Tambakol	42,458	44,194	47,063	51,832	51,882	47,486
7	*Anchoviella* spp. Anchovies (dilis)	43,111	43,220	45,864	49,432	45,815	45,488
8	*Sardinella fimbriata* Fimbriated Sardines/Tunsoy	33,580	37,845	41,258	48,306	61,514	44,501

Stock status

In the Philippines, many of the nation's fishing grounds are over-fished as evident from decreasing CPUE despite expanding fishing fleets and effort (FAO 2010, Olano *et al*. 2009a, Olano *et al*. 2009b, Rueca *et al*. 2009) and the fact that mean standard length of several species is less than that at first maturity (Guanco *et al*. 2009). Fishing pressure exceeded sustainable levels for the resource as early as the 1970s (Pauly 2004) and stock assessments have had bold recommendations to reduce fishing pressure by half to maintain the viability of small pelagic fisheries (Zaragoza *et al*. 2004). A depletion of the fishery can have lasting economic impacts as is evident from the shift of commercial operations away from Manila and Visayas to Zamboanga after the decline in the Visayan sardine fishery from the 1970's to 1980's (S. Swerdloff, pers comm.). Green *et al*. (2003) cites the shift from sardines to anchovies as a sign of a collapsing fishery; however, how much is of this is shift is natural fluctuation and how much due to anthropogenic pressures is difficult to determine. Sardines, together with anchovies, are the most inexpensive source of animal protein available to Filipinos, yet the doubling and tripling, respectively, in wholesale price from 1990 to 2010 (BAS, 2010) may, in addition to increased operating costs, be a harbinger of how this accessible food source may become increasingly inaccessible if stocks continue to decline.

Stock structure of sardines is also one area where immediate study is needed because it is imperative in fishery management plans. Some marine small pelagic species found in the Philippines have been able to maintain connectivity between subpopulations over large geographic areas such as *Euthynnus affinis* (Kawakawa or Eastern Little Tuna) (Santos *et al*., 2010), other species show genetic divides like

Caesio cuning (Redbelly yellowtail fusilier), which has some evidence towards regional population breaks (Ackiss, unpublished data). Catch data, biological characteristics, tagging and genetic analysis are some of the approaches that can be used to study the population structure of sardines. Furthermore, studying sardine phylogeography, the analysis of phylogenetic data on organisms relative to their spatial distribution (Hickerson *et al*. 2010), aids in delineating distinct stocks which is critical for developing sustainable sardine fisheries and moving in the direction of food security.

Biodiversity and Food Security

The number of sardine species found in the Philippines is among the highest reported anywhere in the world (Whitehead 1985). Why exactly there are so many species of sardines in the Philippines shares in the hypotheses of why biodiversity in general is so high in this region (Hoeksema 2007). Exploring which hypotheses are most accurate is a challenging and intriguing scientific exercise, but from the practical perspective, understanding what processes create high biodiversity gives us insight in how to protect both extant sardine diversity and the processes that give rise to future species (Moritz and Faith 1998).

Although data is still lacking in the Indo-Pacific region, studies on temperate sardine populations suggest a long history of repeated collapses and re-colonization of coastal habitat (Grant and Bowen 1998, Lecomte *et al*. 2004, Grant and Bowen 2006). These collapses have been the result of various sub-optimal environmental conditions and genetic data suggested that re-colonizations have been possible because sardines contracted to a refuge and then expanded out from that refuge as favorable conditions returned (Lecomte *et al*. 2004). If such a scenario was shared in the Philippines, indentifying and protecting this source population of high genetic diversity (both inter- and intra-specific) may permit recovery after a fisheries collapse due to natural and/or anthropogenic drivers, given favorable conditions were re-established.

Tawilis concern

Sardinella tawilis is the most important and dominant fish in the open fisheries of Taal Lake. It is mainly caught by gill net, beach seine, ring net and motorized push net (Mutia 2004). Highest production of Tawilis was recorded in 1984 with 29,000 mt (Hargrove 1991, Bleher 1996) followed by 8,798 mt in 1988 (PCTT 1994) and 6,858 mt in 1992 (PCTT 1994). However, its production slowly declined from 744 mt in 1996 to 294 mt in 2000. Exploitation rate (E) obtained for Tawilis was 0.56 which exceeds the optimum range of 0.30-0.50 indicating overfishing of the resource (Mutia 2004). The declining production of Tawilis can be attributed by several factors including overfishing, introduced species, deterioration of lake water quality, and illegal operation of active fishing gear like the motorized push net and ring net. These problems believed to pose a serious threat to Tawilis production and its habitat which may lead to depletion if not extinction in the near future (Mutia 2004).

Overfishing

Local and global pressures threaten Philippine sardine fisheries, of these the most concerning is over-fishing and the prospect of collapsing sardine stocks. The decline of Clupeinae fisheries have previously been documented in the temperate waters of California, Chile/Peru, Namibia and the Korean peninsula (Radovich 1982, Kawasaki 1992, Bakun and Weeks 2006). Natural variation in climatic and oceanographic patterns does cause population fluctuation on a decadal timescale, typically alternating between sardine-dominant (warm-temperature) regimes and anchovy-dominant (cool-temperature) regimes (Schwartzlose et al. 1999, Chavez *et al*. 2003, Skogen 2005). The decline of one fish and the rise of the other is not necessarily a case of niche availability, but can rather be reflective of preferred environmental conditions. Over-fishing, however, can lead to the general decline of the stock if excessive fishing occurs during the early years of a species rise to dominance (Schwartzlose *et al*. 1999). If fishing pressure is severe and geographically concentrated, fragmentation of nursery and adult feeding grounds can inhibit growth of the stock and effectively eliminate any recovery. Such was the scenario along the coast of Namibia where the loss of phytoplankton-consuming sardines lead to the build-up of phytoplankton that fueled an outbreak of zooplanktivores that preyed on fish eggs and larvae, thus further depressing the stocks recovery (Bakun and Weeks 2006).

Overfishing concerns can begin to be alleviated with future studies focusing on indentifying what level of variance is natural and how much of the variance can be attributed to anthropogenic pressures, primarily overfishing. This can be addressed immediately through comparative studies between Philippine stocks and better documented stocks in temperate and sub-tropical waters. At the same time, local studies on the relationship between primary productivity and fish production, annual/decadal variance in fish recruitment of Philippine sardines, effect of harvesting pre-adult individuals on long-term stock success, etc. can make use of existing methods and fill in the gaps as data becomes available.

Climate change

Global climate change is the single greatest threat to human populations via the associated impacts of increased tropical storm frequency and intensity, shifts in weather patterns, alterations to the marine and coastal environments, threats to food security, etc. (IPCC 2007, Wassman *et al*. 2009). If fishery management is to have long-term success, the effects of climate change must be thoughtfully included in forthcoming plans and strategies. The ecological effects of climate change on sardine populations are still being discovered and documented, though several consequences are conceivable. The first is the intensification of coastal upwelling from stronger wind speeds driven by greater discrepancy between land and sea temperatures (Bakun and Weeks 2004). More upwelling would increase the supply of nutrients to the euphotic zone and subsequently primary production, however, increased primary productivity is not necessarily causative of higher fish productivity (Udarbe-Walker and Villanoy 2001, Bakun and Weeks 2008). More intense upwelling could have negative implications on juvenile sardines as Skogen (2005) found that recruits obtained their highest weight in moderate upwelling and lower weights as intensity increased.

Although the impacts of climate change should be of great concern to fisheries management plans, the variance in sardine populations that occurs natural cannot be overlooked. In the temperate waters of the northeast Pacific shifts between the cold, nutrient-rich waters preferred by anchovies and the warmer, less nutrient-rich waters preferred by sardines fluctuate with upwelling on a monthly to yearly to millennial time scale (Lecomte *et al*. 2004), with sardines and anchovies exchanging dominance every 20 to 30 years (Chavez 2003). Likewise, the El Nino Southern Oscillation phenomenon takes place more frequently, every two to six years (An and Wang 2000). Annually, sardine productivity in many parts of the Philippines reaches its peak during the southwest monsoons in the latter half of the year (Dalzell *et al*. 1990, Olano *et al*. 2009). Furthermore, these oceanographic and metrological patterns overlay and disrupt one another creating an even more complex scheme that becomes increasingly difficult to peg to sardine productivity (Chavez *et al*. 2003).

Thus, the best prospect for maintaining sustainable sardine stocks must factor in the expected effects of global climate change while being mindful of naturally occurring short and long-term environmental variability. History has shown that sardine and anchovy populations have peaked, collapsed and subsequently recovered in many of the world's major small pelagic fisheries (Radovich 1982, Kawasaki 1992, McFarlane and Beamish 2001, Lecomte *et al*. 2004). Oceanographic and ecological factors seem to dictate the harmonics of these patterns, yet the addition of unprecedented climate change and extensive overfishing may severely upset these natural cycles. Changes in the Earth's climate have happened before and sardines have survived, although not everywhere. Recent phylogeography studies on temperate anchovies suggest that populations persisted through adverse conditions have been in areas where coastlines permitted them to latitudinally track optimal environmental conditions (Grant and Bowen 2006). In geographically unfavorable locations, such as southern Africa and Australia, populations went extinct and were subsequently re-colonized from northern populations when more favorable conditions returned (Grant and Bowen 1998, 2006). Hence the preservation of refuges and source populations will be necessary. Unfortunately, many of the Philippine fishing grounds are heavily exploited and already suffer from many local pressures. Palawan has recently been identified as an ideal candidate for a network of marine protected areas (MPA) based on models that forecast low thermal stress from climate change and only moderate levels of local impact (McLeod *et al*. 2010). In addition to identifying sardine refuges, research also must be conducted to better understand the diverse life histories of the nine Philippine sardine species so the planning of MPAs and management decisions can be as inclusive as possible. This will not only be critical for affording sardines the opportunity to adapt to climate change, but it will also allow them to continue natural evolutionary processes.

Conclusions

Reviewing the status and threats to sardines in the Philippines is a broad, multi-faceted task and we recognize the synthesis of information presented here is in no way exhaustive of the data available. That being said, we have reported a brief and current snapshot of sardines in the Philippines and have introduced a few ideas that may aid in forthcoming investigations. The socio-economic and ecological values of sardines to the Filipino people cannot be under-stated and establishing a sustainable and productive fishery should not be viewed as definitive endpoint but rather a continual pursuit, especially in light of ceaseless climatic and environmental change. Only by considering the combined insight of laboratory investigations, genetic studies, and field reports can we move towards this necessary goal.

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