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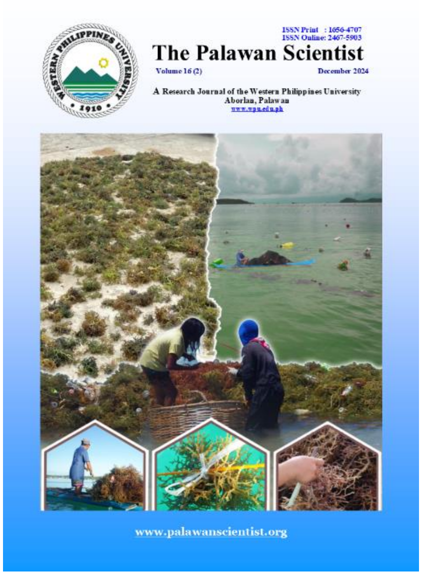

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Demersal stock assessment in Leyte Gulf, Philippines

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ABSTRACT

A demersal stock assessment was conducted in Leyte Gulf from 24 April to 08 May 2020, within the 19 established fishing stations, using a bottom otter trawl with a 71 m length and a 43 m head rope. This study focused on determining the total catch, catch composition, catch per unit effort (CPUE), and biomass. A total catch of 4.22 t comprised of 230 fish species and invertebrates which belongs to 74 families was recorded in the survey. The majority of the catch belongs to family Leiognathidae, comprising 39.45%, followed by Lutjanidae, and Gerreidae, with 8.05% and 7.07%, respectively. Top species were Orangefin ponyfish *Photopectoralis bindus* with a composition of 25.49%, followed by Toothpony *Gazza minuta* (both are locally known as "sap-sap"), and Longfin mojarra *Pentaprion longimanus* "hubad" with 7.42%, and 5.80%, respectively. Mean CPUE and biomass were approximately 222.08 kg hr^{-1} and 2.81 t km^{-2}, respectively. A 68.26% increase in biomass compared to previously conducted study in 2014 of M/V DA-BFAR was recorded. The shifting of catch composition from economically valuable to low-valued, non-targeted, and small-sized species was observed. A continuous resource assessment activity is essential to determine the changes in fishing patterns, catch rates, and catch composition, which will serve as a basis for policy formulation and future management plans and measures.

Keywords: biomass, CPUE, trawl, *Photopectoralis bindus*

INTRODUCTION

Leyte Gulf is among the significant fishing grounds in the Philippines, covering the islands of Samar and Leyte, including San Pedro Bay with an area of 2,724 km^2 (Tan et al. 2017; Francisco et al. 2018; BFAR 2018). The gulf serves as the primary source of food, income, and livelihood for many coastal fishers in the area (Tan et al. 2017). According to Francisco et al. (2018), the average annual fish catch from 2001 to 2011 in the gulf was estimated at 18,308.2 tons (t). Further, as indicated in their study, the trawl fishing gear contributed 16.61% and 4.01% of catch percentages from commercial and municipal fisheries in Leyte Gulf, respectively. However, the use of trawl fishing gear is prohibited under Fisheries Administrative Order (FAO) 201, series of 2000. While it is prohibited, continued fishing operation utilizing trawl fishing gear within the gulf was observed. As mentioned by Kelleher (2005) and Francisco et al. (2018), trawling is one of the most destructive ways of fishing and often leads to overfishing and its operation destroys coral reefs and seagrass beds located in the municipal waters.

Globally, several studies about trawl fisheries and demersal stock assessment were conducted, that includes the analysis of Warfel and Manacop (1950) in the Philippine waters; Silvestre et al. (1987) in Manila Bay; Biradar (1987) in Karnataka Coast, India; Pauly (1988) in Southeast Asia; Smith et al. (2000) in Eastern Mediterranean; Valinassab et al. (2006) in Persian Gulf and Oman Sea; Madrid-Vera et al. (2007) in Southern Gulf of California; Fraser et al. (2007) in North Sea; Hashemi and Valinassab (2011) in West Northern of Persian Gulf Water; Diocton (2016) in Samar Sea; Bendaño et al. (2017) in Manila Bay and Hosseini et al. (2018) in Persian Gulf, Iran. However, published studies particularly in Leyte Gulf in the Philippines are scarce.

In 2014, trawl fishing research in Leyte Gulf recorded a demersal stock biomass of 1.67 t km^{-2} (Dela Cruz 2014), which served as a baseline study as there is no other available recent comprehensive survey in the gulf. However, from 1984 to 1988, Edralin et al. (1992) conducted a survey in the area but data on trawl landings were only gathered from fish landing centers. This study was conducted to provide information on the status of demersal fisheries in Leyte Gulf. Specifically, the study aimed to determine the total catch, catch composition, CPUE, and biomass. The result of this study could be used as the basis for policy formulation, future management plans, and measures for sustainable and optimal utilization of resources.

METHODS

Study Site

A trawl fishing survey was conducted onboard M/V DA-BFAR, a 60 meters (m) and 1,186 gross tonnage (gt) multi-purpose vessel operated by the Bureau of Fisheries and Aquatic Resources (BFAR) from April 24 to May 8, 2020. The sampling was conducted within 19 established fishing stations, situated between the coordinates of 10°31'28.20"N to 11° 8'11.04"N Latitude and 125° 3'52.98"E to 125°39'47.39"E Longitude (Table 1) within the vicinities of the northern (Tacloban City, Palo, Tanauan, Tolosa, Dulag) and southern parts of Leyte (Silago, Abuyog, Mc Arthur), and the eastern part of Samar (Manicani Island, Giporlos, Balangiga, Maslog) (Figure 1).

Table 1. Coordinates of the 19 established fishing station in Leyte Gulf, Philippines.

Station Number	Start		End	
	Start dragging (Latitude, N)	Start dragging (Longitude, E)	End dragging (Latitude, N)	End dragging (Longitude, E)
1	11°03.530'	125°07.660'	11°05.370'	125°03.310'
2	10°56.280'	125°06.570'	10°52.750'	125°09.560'
3	10°46.840'	125°04.020'	10°51.730'	125°03.050'
4	10°45.060'	125°36.850'	10°49.660'	125°34.170'
5	10°57.230'	125°32.190'	10°55.180'	125°27.170'
6	10°52.970'	125°28.960'	10°56.870'	125°24.930'
7	10°53.280'	125°20.930'	10°58.710'	125°16.000'
8	10°59.540'	125°20.930'	11°03.780'	125°18.010'
9	10°57.650'	125°27.470'	11°01.840'	125°25.840'
10	10°53.060'	125°38.200'	10°54.590'	125°33.450'
11	11°00.860'	125°13.380'	10°56.330'	125°10.250'
12	10°54.860'	125°03.190'	10°59.050'	125°05.310'
13	10°49.590'	125°16.880'	10°53.410'	125°13.090'
14	10°47.420'	125°32.330'	10°45.330'	125°27.230'
15	10°50.230'	125°21.280'	10°47.930'	125°25.100'
16	10°46.980'	125°11.110'	10°51.310'	125°13.040'
17	10°41.160'	125°15.810'	10°45.580'	125°18.890'
18	10°39.400'	125°13.760'	10°37.600'	125°19.110'
19	10°32.670'	125°15.280'	10°35.300'	125°19.550'

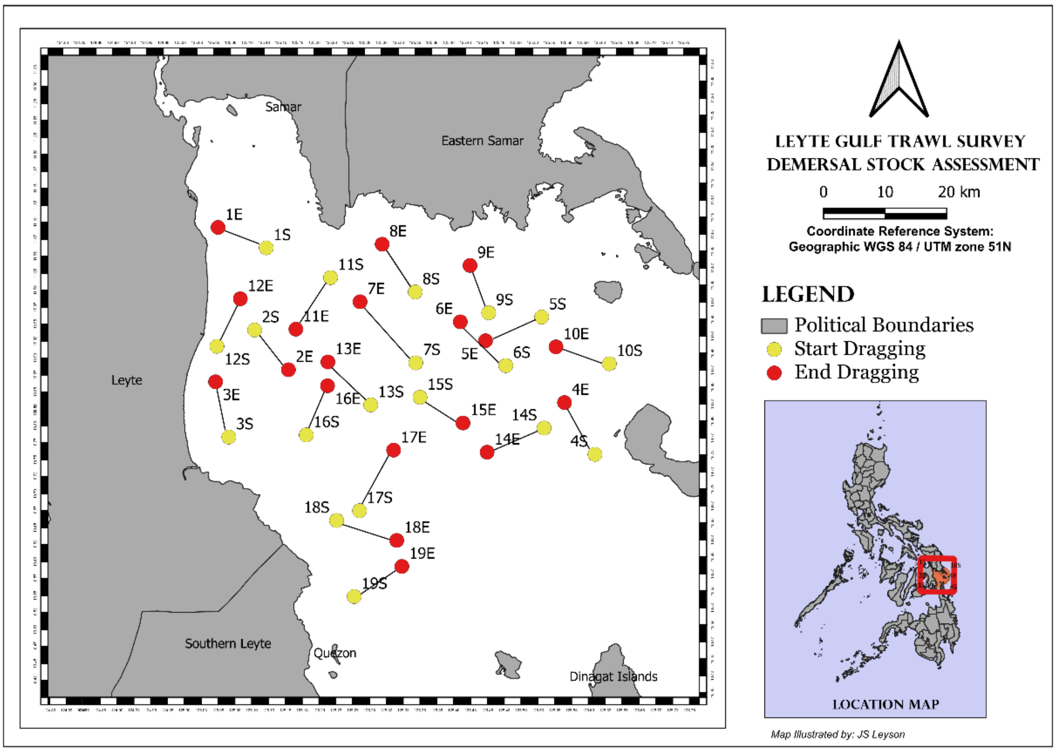

Figure 1. Map showing the 19 established trawl sampling stations in Leyte Gulf, Philippines.

Sampling

An otter trawl measuring about 71 m in length with a head rope of 43 m was used during the survey. Initially, all stations were verified by tracking the area using an acoustic sounder to ensure its suitability for trawl operations. Trawling was done during the daytime and dragging time was maintained at one hour or whenever possible (trawl operations are vulnerable to unexpected damage to the gear during dragging). Trawl operations were assisted by M/V DA-BFAR officers and crew for manpower. Fishing details and other relevant data were recorded in specific forms. Depth, dragging speed, and dragging duration are reflected in Table 2.

Catch was poured on deck, if the total catch was workable, all the catch was treated as samples. However, if not, samples were mixed homogenously to avoid bias and sub-samples were taken randomly from this. Samples were categorized as population (big and rare species) and sub-samples. Big-sized fish individuals quickly taken from the pile first and was separated, identified, and weighed. Sub-samples were segregated according to groups and was identified to the nearest possible taxon with the aid of various fish identification guides (Nakabo 2002; Allen et al. 2003; Gonzales 2013; Alava et al. 2014). The weight of every species in the sub-samples per station were subsequently raised from the total catch.

Data Analyses

The total catch in tons (t) was computed by adding the catch of all sampling stations. Catch composition was categorized by species and family, calculated by dividing the weight of specific species or families by the total catch weight, and then multiplied by 100 to determine the relative abundance (%).

For calculating the CPUE values, the total catch weight (kg) was divided by the dragging duration in hours (hr).

Formula 1:

$$\text{CPUE} = \frac{\text{total weight (kg)}}{\text{dragging duratin (hr)}}$$

The Biomass in tons per square kilometers (t km^{-2}) was computed following the concept of swept area method and expressed as;

Formula 2:

$$B = 2\,\frac{\text{catch (t)}}{\text{swept area}}$$

Two (2) is constant (the catch rate is twice the standing biomass to account for escapement) (Sparre and Venema 1998).

The swept area method was estimated as follows:

Formula 3:

$$a = D{*}hr{*}\ X_2,\ \text{where } D = V{*}t$$

Where (a) total area swept by the gear; (D) distance swept, (V) velocity of the trawl over the ground when trawling, (t) time spent for trawling, (hr) is the length of the head rope and X_2 is the fraction of the head rope length which is equal to the width of the path swept by the trawl and the wing spread. The value of X_2 used was 0.5 as a compromised value suggested by Bendaño et al. (2017). Data consolidation and analysis were done using Microsoft Excel. The results are presented in tables and graphs.

Table 2. Average depth (m), dragging speed (km hr^{-1}) and dragging duration (hr) of each station during trawl survey in Leyte Gulf.

Stations	Depth (m)	Dragging Speed (km hr^{-1})	Dragging Duration (hr)
1	28	7.22	1.00
2	42	7.22	1.00
3	38	7.41	1.00
4	89	7.96	0.98
5	88	7.59	1.05
6	100	7.04	1.02
7	101	7.59	1.78
8	76	7.04	1.03
9	89	7.41	0.67
10	94	6.85	1.00
11	60	7.22	1.02
12	24	7.04	1.00
13	93	7.41	1.00
14	103	8.52	1.03
15	111	7.41	1.02
16	75	6.30	0.98
17	101	7.22	1.03
18	89	7.59	1.12
19	96	6.11	1.10
Average	**79**	**7.27**	**1.04**

RESULTS

Total Catch

This trawl survey recorded a total catch of 4.22 t of fish and invertebrates with about 33,839 individuals belonging to 74 different families, which comprised 230 identified species (202 fishes, 7 cephalopods, 11 crustaceans, 6 echinoderms, and 4 mollusks) however, 14 samples or 5.74% remained unidentified.

Catch Composition

The majority of the catch belongs to Family Leiognathidae (locally known as “sap-sap”), comprising 39.45% (12 species), followed by Lutjanidae “maya-maya”, and Gerreidae “amurok”, with 8.05% (6 species), and 7.07% (5 species), respectively. Additionally, other families such as Mullidae “salmonyete” (5.64%, 6 species), Nemipteridae “bisugo” (4.92%, 15 species), and Carangidae “talakitok” / “matambaka”, “galunggong” and “tonto” (4.64%, 24 species), and Dasyatidae “pagi” (4.09%, 3 species) also dominated the catch (Figure 2). The occurrence of families Loliginidae “pusit”, Carcharinidae “pating”, and Myliobatidae “pagi”/eagle ray were recorded. Further, the dominance of the non-commercially important family like Fistularidae was also documented.

The Orangefin ponyfish *Photopectoralis bindus* dominated the catch during the recent survey in Leyte Gulf with a composition of 25.49%, followed by Toothpony *Gazza minuta*, and Longfin mojarra *Pentaprion longimanus* with 7.42%, and 5.80%, respectively. The presence of shark (Silky shark *Carcharinus falciformis*) (0.98%) and stingray (Jenkins whipray *Pateobatis jenkinsii*) (3.55%) species, as well as the Indian squid *Uroteuthis duvaucelli* (1.07%) were noted in top 20 dominant species (Figure 3). Aside from the top 20 dominant species in the area, the gulf is also rich in highly valued/commercially important species such as Yellow spotted trevally *Carangoides fulvoguttatus* (0.08%), Areolate grouper *Epinephelus areolatus* (0.3%), Narrow-barred spanish mackerel *Scomberomorus commerson* (0.24%), Yellowtail amberjack *Seriola lalandi* (0.63%), and Black-banded trevally *Seriolina nigrofasciata* (0.58%).

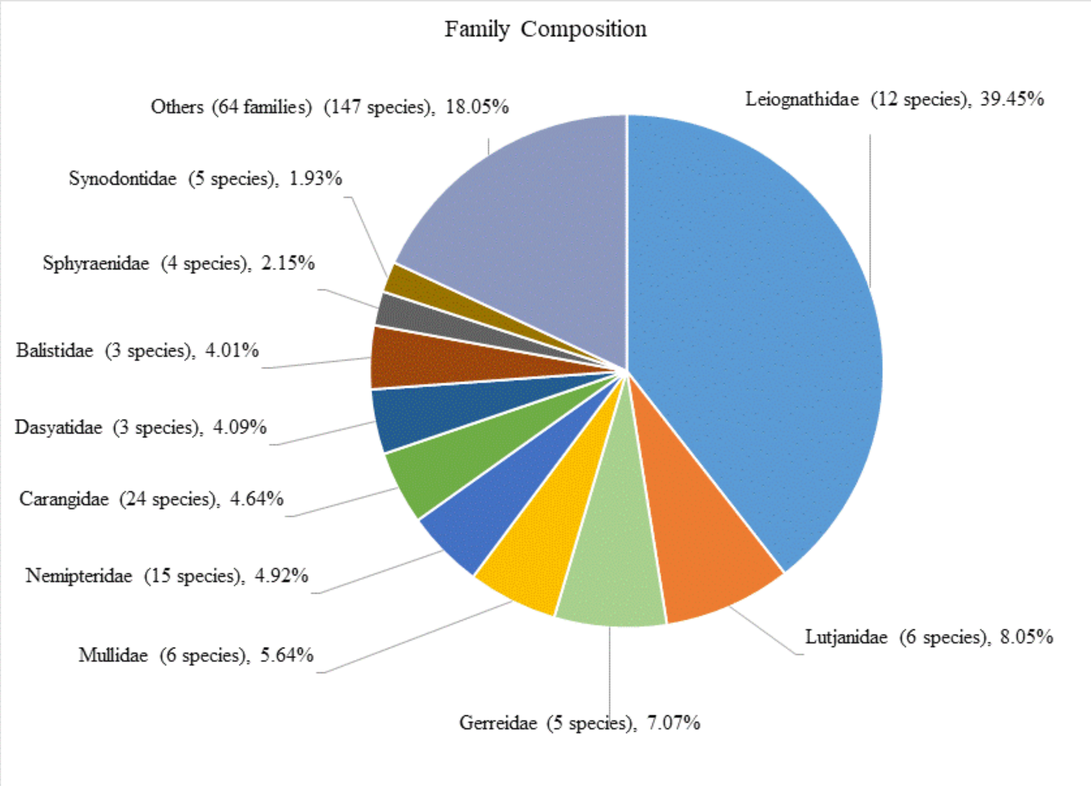

Figure 2. Top 10 families caught during the trawl survey in Leyte Gulf.

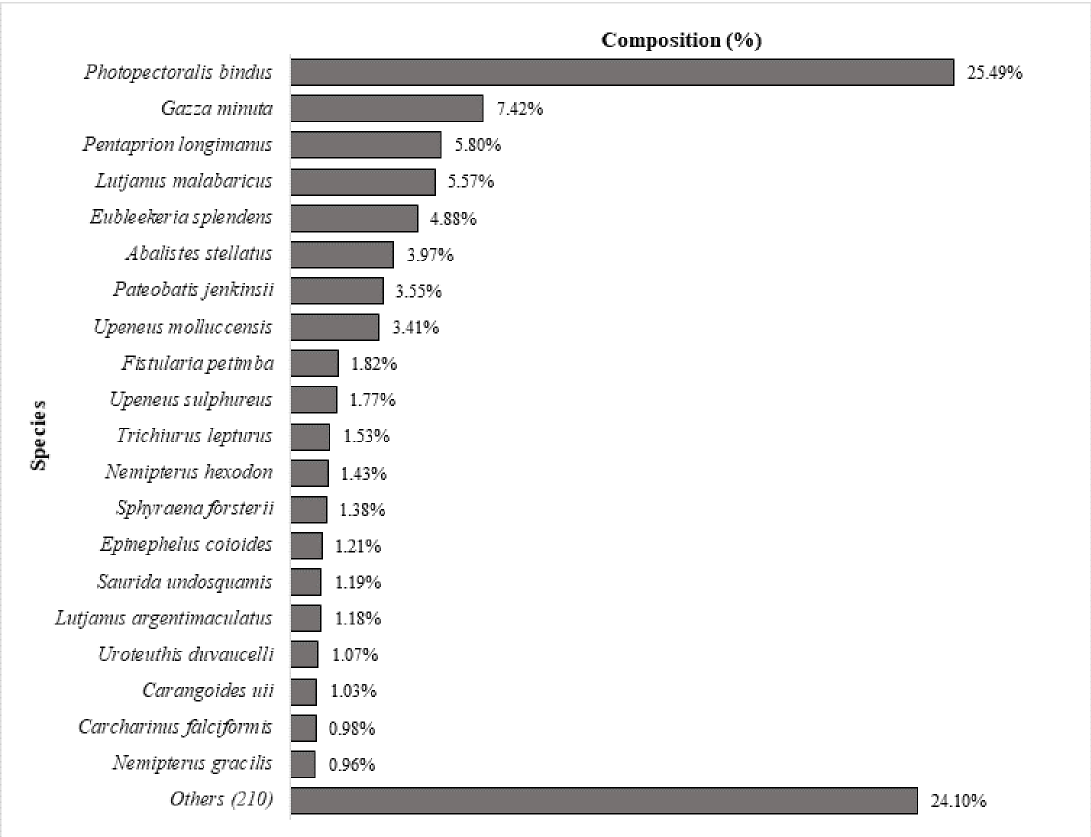

Figure 3. Top 20 species during trawl survey in Leyte Gulf.

Catch Per-Unit-Effort (CPUE)

The CPUE varies in every station during the recent trawl fishing survey in the gulf. An average CPUE of 222.08 kg hr^{-1} was recorded. Noticeably, Station 9 recorded the highest CPUE among other stations with 74.20 kg hr^{-1}, while the lowest was at Station 19 with 8.90 kg hr^{-1} (Figure 4).

Biomass

As shown in Figure 4, the computed biomass in every station differs from each other, with Station 9 having the highest (9.97 t km^{-2}) and Station 19 having the lowest (0.14 t km^{-2}). The recorded average biomass was at 2.81 t km^{-2}.

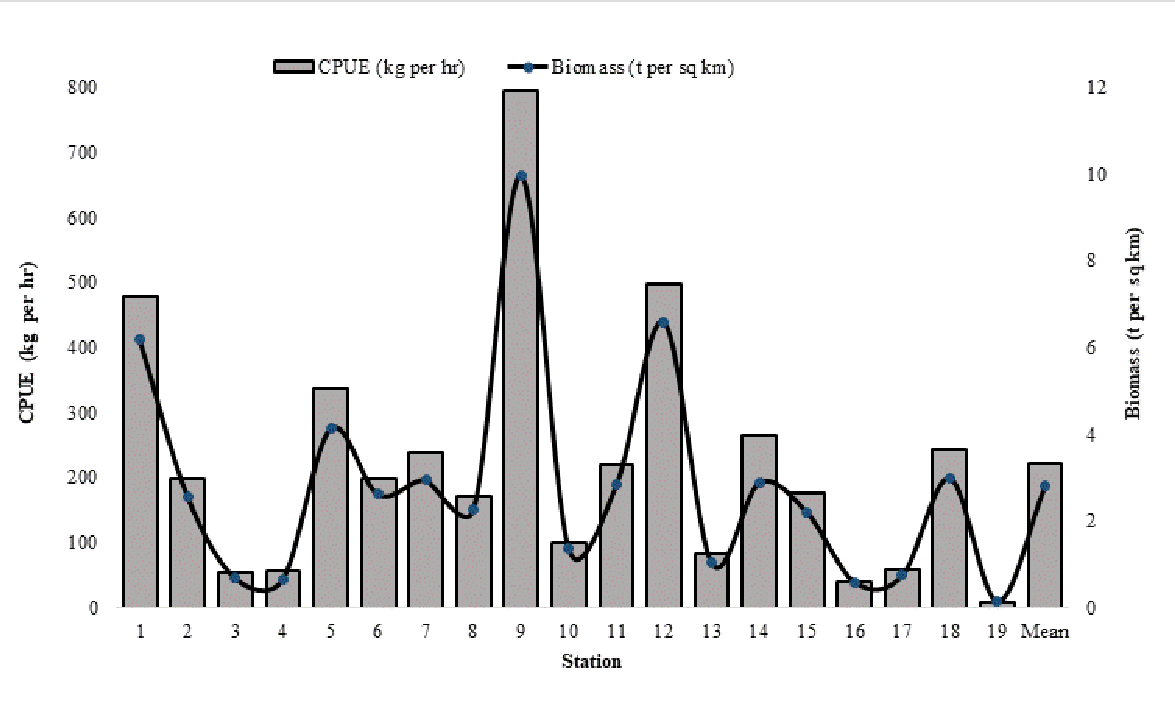

Figure 4. Computed Catch Per-Unit-Effort (CPUE) and biomass per station in Leyte Gulf, Philippines.

DISCUSSION

Total Catch

The total recorded catch in this study was 4.22 t which is found to be much higher than the previous survey in 2014, with 3.10 t (36.13% increased). On the contrary, Edralin et al. (1992) documented a relative decline in catch of 99.7% from the five-year fish landing survey in Leyte Gulf from 1984 to 1988. Additionally, the result of this study is much higher than the recorded catch from West Basilan-Sulu Shelf and Turtle Island, Tawi-Tawi, with only 2.48 t and 0.67 t total catch, respectively (Ramiscal et al. 2008; Dela Cruz 2016). However, the total catch in the gulf was found to be lower than in Manila Bay (Bendaño et al. 2017) and Samar Sea (Diocton 2016), with 8.14 t and 298.5 t, respectively. This could indicate that the stocks are recovering due to a combination of management measures in Leyte Gulf, as discussed in the works of Pipitone et al. (2000), McClanahan et al. (2006 a, b), Samoilys et al. (2007), Alcala et al. (2008), Yamazaki et al. (2014), and Chirico et al. (2017).

Catch Composition

The Family Leiognathidae dominated the catch in Leyte Gulf, specifically the species of *P. bindus* and *G. minuta*. Similarly, in San Miguel Bay, the dominance of the small-sized Leiognathids such as *P. bindus*, *Secutor ruconius*, and *S. insidiator* was noted (Pauly and Mines 1982). In Lingayen Gulf, Leiognathidae was the top family in trawl catches during the late 1940s, 1970s, and 1980s (McManus and Chua 1990).

The *P. bindus*, and *G. minuta* belongs to a low trophic level (3 and 4.2, respectively) which are smaller in size and non-targeted (Murugesan et al. 2012). In comparison, herbivores and detritivores are assigned to a trophic level 2, while most marine mammals comprise a trophic level ranging from 3 to 5 (Trites 2019). The dominance of Leiognathids in the Lingayen Gulf is an indication that the demersal stocks are heavily fished (Villoso and Aprieto 1983). In 1988, Edralin et al. (1992) stated that Carangidae and Scombridae dominated the catch, with *Decapterus macrosoma* and *Rastrilleger kanagurta* as the most dominant species in Leyte Gulf. However, in this study, these families only ranked 6th and 13th, respectively. The decrease in the composition of targeted fish families like Carangidae and Scombridae was notable in the Samar Sea, with an increasing composition of non-targeted species (e.g., slipmouths/ponyfish) (Dela Cruz and Gino 2017). With these findings, annual resource assessment activity within the gulf is needed to determine the changes in fishing pattern, catch rates and catch composition.

The shifting of catch composition from economically valuable species to low-valued species and the dominance of low trophic level species suggests an overexploited fishing ground and deterioration in fisheries (Edralin et al. 1992; Bendaño et al. 2017). This situation also happened in the Gulf of Thailand (Supongpan 2001). Additionally, various studies claimed that the increased in the abundance of forage or bait fish is mainly due to the cascading effects caused by decreasing predator abundance because of human exploitation (Carscadden et al. 2001; Worm and Myers 2003; Coll et al. 2013; Christensen et al. 2014). Moreover, a decreasing trend of trawl landings and fish catch noted in the gulf was mainly due to recruitment overfishing, the occurrence of illegal fishing in the area, and the number of fishers (Edralin et al. 1992, Francisco et al. 2018). The dominance of Leiognathids in the area and the presence of some high-valued species suggest that some part of the area is replenishing its stock. A diverse number of species identified in this study is comparable with the studies of Ramos et al. (2018) but much lower than Olaño et al. (2009 a, b) and Dela Cruz and Gino (2017). On the other hand, the results were found to be higher than other studies (Table 3). This study proved that the Leyte Gulf harbors an abundance of marine resources. According to Francisco et al. (2018) and Tan et al. (2017), the gulf is the principal fishing grounds in the Philippines, and it serves as the source of livelihood, food, and income for many of the coastal communities. Relative to this, a socio-economic survey should be conducted to distinguish the profit of the fisherfolks that mainly rely on the resources of the gulf.

Table 3. Different trawl study areas in the Philippines with number of family and species observed.

Area	No. of Family	No. of Species	Author
Lingayen Gulf	80	166	Aprieto and Villoso 1982
Turtle Islands, Tawi-Tawi	50	150	Ramiscal et al. 2008
Sorsogon Bay	73	270	Olaño et al. 2009a
Lagonoy Gulf	106	658	Olaño et al. 2009b
West Basilan-Sulu Shelf	55	184	Dela Cruz 2016
Samar Sea	-	117	Diocton 2016
Manila Bay	48	146	Bendaño et al. 2017
Visayan Sea	81	247	Dela Cruz and Gino 2017
Tayabas Bay	58	230	Ramos et al. 2018
Leyte Gulf	74	230	This study

Catch-Per-Unit-Effort (CPUE)

The CPUE is an index of the abundance of supply in the wild and an important indicator for the fishery (Hoggarth et al. 2006), usually obtained by interviewing fishers upon landing their catch. In this study, the CPUE was based on an actual trawl fishing operation. The average CPUE (222.08 kg hr^{-1}) recorded is much higher than the results of Francisco et al. (2018) with 27.7 kg hr^{-1}, Ramiscal et al. (2008) with 61 kg hr^{-1}, and Bendaño et al. (2017) with 79.6 kg hr^{-1}. The station with the highest CPUE recorded was mainly due to the higher total catch and shorter dragging time among other stations. It is worth noting that Station 19, located in the southern part of Leyte, recorded a high abundance of *Lutjanus malabaricus*. As this assessment is limited to a one-hour dragging duration at each station, it is advisable to perform observations and sampling on the municipal boats and gears operating in the gulf to yield a more comprehensive dataset for calculating CPUE.

Biomass

The recorded average biomass in this study (2.81 t km^{-2}) was about 68.26% higher than the average biomass recorded during the 2014 trawl survey in the area (Dela Cruz 2014). In comparison with the demersal trawl survey conducted by M/V DA – BFAR in various fishing grounds in the Philippines, the average biomass of Leyte Gulf during the recent study was found to be higher than Davao Gulf, which only had an average biomass of 0.13 t km^{-2}, and the Visayan Sea with 1.63 t km^{-2} and 1.55 t km^{-2} average biomass during the 2007 and 2016 surveys, respectively. The highest biomass in the country was estimated in Samar Sea (3.72 t km^{-2}) and West Basilan-Sulu Shelf (3.69 t km^{-2}). The computed biomass of other significant fishing grounds was reflected in Table 4.

Assessment of the status of fisheries using trawl surveys in various major fishing grounds in the Philippines began in the late 1950s up to these days.

The recorded biomass in this study is comparable with the results in Imuruan Bay and Bacuit Bay in Palawan (Ronquillo and Gabral-Llana 1987) but relatively higher in other previous studies in the Philippines (Table 5). The increase in biomass is a result of the implementation of various management measures in Leyte Gulf, such as the establishment of marine reserves and implementation of several laws and ordinances. No-take zones were used in marine reserves as a conservation and the management strategy for the sustainability of marine resources (Yamazaki et al. 2014). In the report of Alcala et al. (2008), Leyte and its associated islands have 77 no-take zone marine reserves. The Binangalan and Sag-ang Fish Sanctuaries were the two established marine reserves in Leyte Gulf. Moreover, the establishment of community Marine Protected Areas (MPAs) increases the biomass and size of reef-associated fish and the density of fish families (McClanahan et al. 2006; Samoilys et al. 2007; McClanahan et al. 2016b; Chirico et al. 2017). As part of the management measures, the Local Government Unit (LGU) of Leyte created Ordinance No. 02, Series of 2017, “Amended municipal basic fishery ordinance of the Municipality of McArthur, Leyte”. In pursuant to Fisheries Administrative Order 201, series of 2000 and provided in Department of Agriculture - Administrative Order No. 10, series of 2015, the ban on fishing with active gears within the municipal waters, bays, and fishery management areas was implemented nationwide. A year-round trawling ban and illegal fishing regulations are suitable for fish biomass increase (Pipitone et al. 2000; Yamazaki et al. 2014). During the survey, law enforcers approached the vessel since it was publicly known that trawl is an active gear and is prohibited.

Table 4. Computed biomass (t km^{-2}) of the demersal trawl survey conducted by M/V DA-BFAR in various fishing grounds.

Fishing Ground	Year	Biomass (t km^{-2})	Authors/Source
Visayan Sea	2003	2.08	MV DA-BFAR, GTZ
	2007	1.63	MV DA-BFAR, UPV, Guests
Turtle Island, Tawi-Tawi	2008	2.35	MV DA-BFAR
	2011	2.24	MV DA-BFAR
Visayan Sea	2013	3.09	MV DA-BFAR, BFAR 5,6,7,8
Samar Sea		3.72	MV DA-BFAR, BFAR 5,6,7,8
Davao Gulf	2014	0.13	MV DA-BFAR, BFAR-XI
West Basilan-Sulu Shelf	2015	3.69	MV DA-BFAR, BFAR 9 & ARMM
Visayan Sea	2016	1.55	MV DA-BFAR, BFAR 5,6,7,8
Samar Sea		2.24	MV DA-BFAR, BFAR 5,6,7,8
Palawan		3.20	MV DA-BFAR, NFRDI, NSAP
Visayan Sea	2017	2.77	MV DA-BFAR, BFAR 5,6,7,8
Samar Sea		1.80	MV DA-BFAR, BFAR 5,6,7,8
Leyte Gulf	2020	2.81	This study

Table 5. Computed biomass (t km^{-2}) of the demersal trawl survey in other fishing grounds in the Philippines.

Fishing Ground	Year	Biomass (t km^{-2})	Authors/Source
Manila Bay	1947	4.61	Warfel and Manacop 1950
	1968-72	1.71	Silvestre et al. 1987
Malampaya Sound, Palawan	1977-78	6.5-9.7	Ronquillo and Gabral-Llana 1987
Imuruan Bay, Palawan		2.0-2.8	
Bacuit Bay		2.7-3.8	
Manila Bay		0.8-1.2	
Lingayen Gulf	1978-79	1.33	Villoso and Aprieto 1983
San Miguel Bay	1979-82	2.13	Mines et al. 1986
San Pedro Bay	1994-95	1.73	Armada 1996
Manila Bay	2014	0.32	Bendaño et al. 2017
	2015	0.48	
Leyte Gulf	2020	2.81	This study

However, the objective of the survey was later explained to the enforcers which is for research purposes only. These management measures, along with strong enforcement, may have contributed to the increase in biomass in the area.

The shifting of catch composition from economically valuable species to low valued, non-targeted and small-sized species is notable in the gulf. The presence of Leiognathids as a dominant species signifies that the area is already over-exploited. High CPUE recorded in the area is mainly due to higher catch with shorter dragging time. Further, the increase in biomass is documented in Leyte Gulf based on 2014 to recent year of trawl survey. These findings suggest to have a continuous observation and strict implementation of the existing laws and regulations to prevent the decline of fishery resources in the gulf.

FUNDING

The Department of Agriculture-Bureau of Fisheries and Aquatic Resources (DA-BFAR) funded this study.

ETHICAL CONSIDERATIONS

This research followed the standard procedure in the conduct of the study and in handling the captured marine organisms.

DECLARATION OF COMPETING INTEREST

The authors declare that there are no competing interests to any authors.

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