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Diet composition based on stomach content of the Streaked spinefoot (*Siganus javus*) from three coastal bays in Mindanao, Philippines

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Abstract. Stomach content analysis was used to quantify diet composition in the Streaked spinefoot (*Siganus javus*). Modified Pinkas Index of Relative Importance (IRI) as well as Costello method of prey importance was used to determine feeding strategy of *S. javus* within, between, and among populations. *S. javus* fed mainly on algae, sponges, seagrasses, and some minute amounts of detritus, amphipods, and other materials of unknown origin, making *S. javus* an omnivorous feeder, with preference on plant material. Costello method of prey importance also showed that *S. javus* is a trophic specialist omnivore as much of its diet is composed mainly of algae, particularly red algae, and varying amounts of seagrasses, zoobenthos and detritus. The presence of detritus and some plastic fibers in the gut of *S. javus* suggest that diet of an animal depends usually on the availability of the resources in different habitats.

Key Words: Diet composition, *Siganus javus*, relative importance, Pinlas Index, omnivore.

Introduction. The study of the feeding habits of fish and other animals based upon analysis of stomach content has become a standard practice (Hyslop 1980; Zacharia & Abdurahiman 2004). Stomach content analysis provides important insight into fish feeding patterns. However, the gut contents only indicate what the fish would feed on. Accurate description of fish diets and feeding habits also provides the basis for understanding trophic interactions in aquatic food webs. Diets of fishes represent an integration of many important ecological components that included behavior, condition, habitat use, energy intake and inter/intra specific interactions (Zacharia & Abdurahiman 2004). Furthermore, the investigation of the diet of a particular fish species is a valuable tool, aiding in the interpretation of the trophic relationships established in water ecosystems (Lima-Junior et al 2006) by providing information about the life of the fish, such as its position in the food web, the food resources it uses and its possible competitors (Schoener 1974; Lima-Junior et al 2006).

Quantitative assessment of food habits (Zacharia & Abdurahiman 2004) is important in the conservation of biodiversity, natural resources, and fisheries management (Ibañez et al 2007). A good quality brood stock is of paramount importance in aquaculture, and studying the natural diet of the fish will provide useful information in formulating management strategy options in aquatic species fishery such as the streaked spinefoot (*Siganus javus*) (Figure 1). Until now, no research has been conducted to assess the food habits and the body shape variations of *S. javus* (Linnaeus 1766) in Mindanao, Philippines. It is argued that the knowledge generated from the study could provide baseline information for the ecology and proper management of the fish in aquaculture.

Figure 1. *Siganus javus*.

Material and Method

Collection of fish samples. *S. javus* samples were collected in three coastal bays in Mindanao, Philippines (Figure 2). They were placed in a styrofoam box and brought to the lab for analysis.

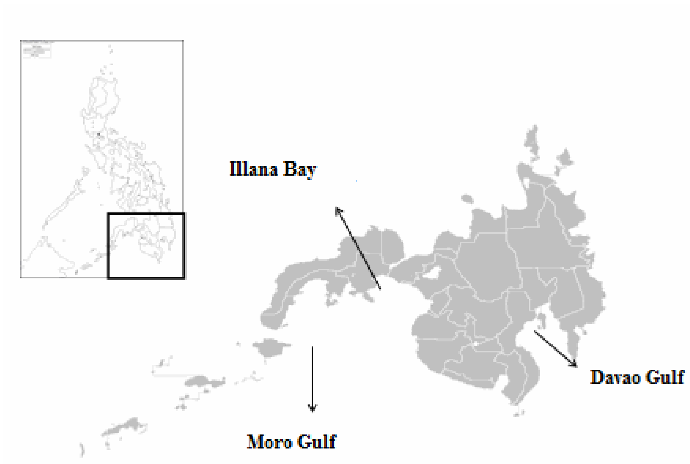

Figure 2. Map of the Philippines showing the approximate locations of Illana Bay (07°30′N 123°45′E), Moro Gulf (06°54′N 123°78′E), and Davao Gulf (6°7'N 125°11'E) study area indicating three sampling stations.

Stomach content analysis. The digestive tracts of male and female *S. javus* were removed and the anterior third section of the digestive tract length containing the more recently ingested food, which is in a better state for identification were used for gut composition analysis (Lima-Junior et al 2006). Stomach contents were extracted and placed in a test tube with 70% ethanol (dissolving any mucus that binds the food) and shaken to dislodge the food items. The residue was decanted and transferred into a Petri dish separating the food items for identification. The food items were identified under a USB microscope with 400X magnification (Cailliet et al 1986) and aided with a field guide (Calumpong & Meñez 1997).

Only the immediate foregut (e.g., stomach) was sampled to avoid bias where both easily digested prey and resistant prey can be observed. According to Zacharia & Abdurahiman (2004), all recently consumed taxa may be present in the foregut but only resistant items remain in the hindgut.

Diet composition was evaluated according to the method of Cailliet et al (1986) such as frequency of occurrence (%F), dry weight biomass (%B), and volumetric weights (%V). Combinations of the three separate measures of prey importance may allow a more representative feeding-habit data summary yet still allow each measure to be evaluated individually.

Frequency of occurrence indicates the number of stomachs each item occurs and is expressed as a percentage of the total number of stomachs examined. This was obtained using the formula developed by several authors (Hynes 1950; Hyslop 1980; Bowen 1983; Lima-Junior et al 2006):

Frequency of Occurrence, Fi = 100ni / n

Where:

Fi: frequency of occurrence of the *i* food item in the sample;

ni: number of stomachs in which the *i* item is found;

n: total number of stomachs with food in the sample.

Volumetric importance. Volumetric weights' importance was obtained using water displacement method. Each of the identified food items was dropped into a 10-mL graduated cylinder and displacement of water was recorded (Zacharia & Abdurahiman 2004).

Regarding dry weight biomass, food items were oven dried at 90^o for day 1, and at 60^o for day 2 until it reached to its constant weight (Gorospe & Demayo 2008).

Measures of prey importance. Modified Pinkas Index of Relative Importance (IRI). A graphical representation of modified Pinkas method was used to describe feeding habits of *S. javus*. Modified index of relative importance was calculated using the formula:

Modified IRIi = (%Vi + %Bi) %Fi

Where, Bi, Vi and Fi represent percentages of biomass, volume and frequency of occurrence of prey i respectively.

Costello's graphical method is another measure that was used to describe prey importance of *S. javus*. This combines the percentage of volume values in the y-axis and frequency of occurrence values in the x-axis. Prey points located near 100% of occurrence and 100% volume shows that the predator is a specialist for a given prey. On the other hand, prey points located near 1% of occurrence and 1% of volume shows that the predator consumed different preys in low quantity, an example of generalist species for a given prey (Gorospe & Demayo 2008).

Measures of trophic diversity. Shannon-Wiener diversity index (H') was used to measure diet diversity (Prey diversity). It was calculated using the following equation:

$H = -å P_i(InP_i)$

Where, P_i is the proportion of each different food item (which may be either relative biomass volume, or frequency of occurrence), contributing to the whole diet (Cailliet et al 1986).

Prey evenness and dominance. The first measure (e) assesses diversity relative to maximum possible diversity if all items shall be represented equally, and therefore it measures how evenly the prey species are distributed in the diet (Cailliet et al 1986). It was calculated as follows:

$$e = H/ H_{max}$$

Where;

H_{max} is the natural log of the number of food types (ln S).The value ranges from 0-1.0, with the higher number indicating maximum evenness, given the number of prey species involved.

The Index of Dominance, measures the extent to which one or a few species dominate in the diet, and it can be expressed simply as:

$$d=\sum_{i=1}^{N} (P_i)^2$$

Results and Discussion. Diet of *S. javus* from three bays in Mindanao include 4-10 prey items that were found in the gut of males while 8-11 prey items were found in the gut of females (Table 1). The prey items were algae, plants, zoobenthos, detritus, and others. The algae observed include Rhodophyta (red algae), Chlorophyta (green algae) and Heterokontophyta (brown algae). The red algae species were *Gelidiella sp, Gracilaria sp., Kappaphycus sp, Mastophoro rosea, Eucheuma sp., and Hypnea sp*. Only one green alga *Enteromorpha sp*. and brown alga *Sargassum sp*. were observed. The marine plants were the seagrass species *Cymodocea sp.,* and *Halodule sp*. Zoobenthos observed were sponges, amphipods, and spats of univalves. Detritus include amorphous materials of plant, animal or of unknown origin (Figure 3). Other materials observed were red plastic fibers and pieces of aluminum foil (Table 1). Only 1-5 prey items were observed to be ingested per fish indicating individuals used only small subsets of the population's niche (Bolnick et al 2002; Gorospe & Demayo 2008).

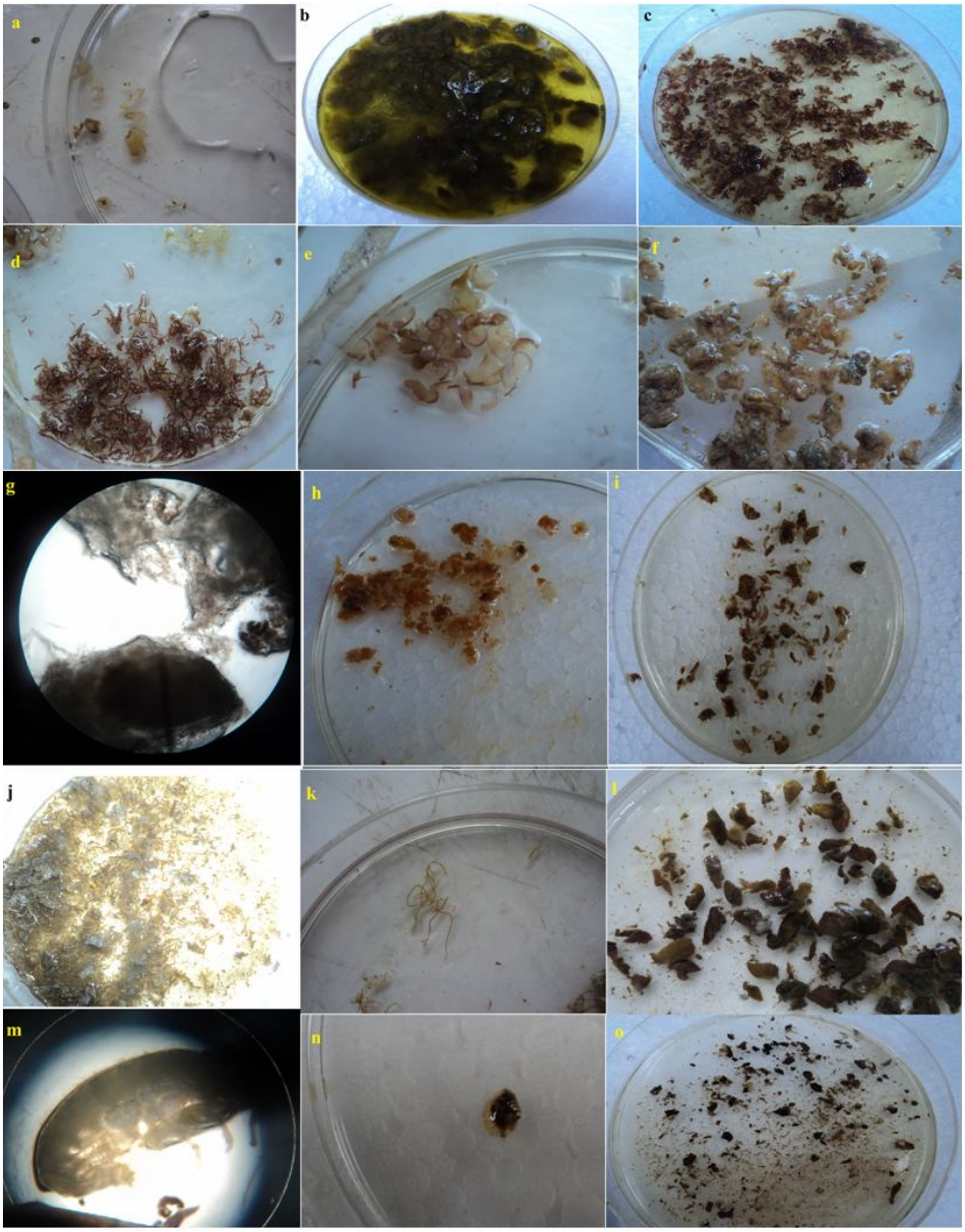

Figure 3. Prey items observed in the gut of *Siganus javus*: (a) *Hypnea* sp., (b) *Enteromorpha* sp., (c) *Gelidiella* sp., (d) *Gracilaria* sp., (e) Kappaphycus, (f) *Mastophora rosea,* (g) brown sponge, (h) orange sponge, (i) *Cymodocea* sp., (j) Sargassum, (k) *Halodule* sp., (l) amorphous material, (m) amphipod, (n) univalve, (o) detritus.

Table 1
Food and feeding habit characteristics of *Siganus javus* from 3 bays in Mindanao, Philippines

Specification	*Illana Bay*		*Moro Gulf*		*Davao Gulf*	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*
Prey items	4	9	9	11	10	8
Prey items/individual	1-2	1-5	1-4	1-4	1-5	1-4
Mean prey items/individual	1.5	1.76	2.82	2.82	2.26	2.10

A closer look at *S. javus* collected in Illana Bay show 4 prey items in the gut of males and nine items in the female gut. The four items found in the gut of males have percentage volume, dry weight biomass and frequency shown in table 2. The green alga *Enteromorpha sp.* was the most preferred food item while the rarest prey item was *Gelidiella sp*. The prey items with the least frequency are *Cymodocea* and *Gelidiella*. Based on frequency of prey items the ranking of preferred food items was *Enteromorpha sp.*> orange sponges> *Gelidiella sp.*>*Cymodocea sp*. The orange sponge, *Enteromorpha sp.* and *Cymodocea sp. we*re the major food items that contribute to biomass dry weight of male gut contents. Sponges increased their importance when dry weight biomass is considered for having higher density compared to other prey items (Gorospe & Demayo 2008).

The female fish caught from the bay preferred the red alga *Gelidiella sp.,* while the rarest prey items were the *Amphipod, Hypnea sp*. and gastropod. The prey items with the least frequency were *Cymodocea sp., Hypnea sp.,* amphipod and gastropod. The ranking of preferred food items was *Gelidiella sp.*>*Kappaphycus sp*.> *Mastophora rosea*. The *Gelidiella sp.*, *Enteromorpha* and *Mastophora rosea* were the major food items that contribute to the biomass dry weight of female *S. javus*.

Table 2
Gut content composition in *Siganus javus* from Illana Bay showing indices of diet importance

Gut content composition	*Male*			*Female*		
	Volume (%)	*Biomass (%)*	*Frequency (%)*	*Volume (%)*	*Biomass (%)*	*Frequency (%)*
			Plant - Seagrass			
Cymodocea sp.	20	20	12.5	12.5	11.51	12.50
			Algae - Red Algae			
Gelidiella sp.	3.34	8.28	12.5	38.15	39.87	50.00
Kappaphycus sp.	0	0	0	1.23	1.1	25.00
Mastophora rosea	0	0	0	14.95	16.11	25.00
Hypnea sp.	0	0	0	0.01	0.08	12.50
			Green Algae			
Enteromorpha sp.	36.66	31.72	25	19.14	16.79	0
			Zoobenthos			
Amphipod	0	0	0	0.03	0.04	12.50
Gastropod	0	0	0	0.01	0.23	12.50
Orange sponge	40	40	25	14.29	14.27	12.50

For *S. javus* from the Moro Gulf, algae, zoobenthos and seagrasses were the main food items of the male fish. The rarest and with the least prey items were *Cymodocea sp.*, *Enteromorpha sp*. and amorphous materials. The ranking of preferred food items were *Kappaphycus*>*Sargassum sp.*>brown sponges. The brown sponges, *Gracilaria sp.* and *Sargassum sp.* were the major food items that contribute to weight of *S. javus* male gut contents (Table 3).

For female individuals, algae, zoobenthos and seagrasses were the main food items consumed. The rarest prey items were orange sponges, gastropod and plastic fiber. The frequency of prey items in the gut shows the ranking of preferred food items to be *Enteromorpha sp.>Sargassum sp.>Kappaphycus sp.* The prey items with the least frequency are the orange sponges, plastic fiber, and *Halodule sp*. The percentage dry weight biomass of gut contents shows that *Enteromorpha sp.*, *Sargassum sp.* and *Gracilaria sp. we*re the major food items that contribute to weight of gut contents in females (Table 3).

Table 3

Gut content composition in *Siganus javus* from Moro Gulf showing indices of diet importance

Gut content composition	*Male*			*Female*		
	Volume (%)	*Biomass (%)*	*Frequency (%)*	*Volume (%)*	*Biomass (%)*	*Frequency (%)*
Plant - Seagrass						
Cymodocea sp	2.78	8.71	10.00	3.87	3.42	10.00
Algae - Red Algae						
Gelidiella sp	9.34	10.77	20.00	6.77	11.63	20.00
Gracilaria sp	15.55	22.59	30.00	12.24	12.66	30.00
Halodule sp	0	0	0	3.12	6.71	0
Kappaphycus sp	14.43	7.71	50.00	18.3	10.32	50.00
Green Algae						
Enteromorpha sp	2.78	0.59	10.00	25	22.67	10.00
Brown Algae						
Sargassum sp	27.22	18.98	50.00	16.02	14.18	50.00
Zoobenthos						
Gastropod	5.45	5.06	30.00	0.91	0.55	30.00
Orange sponge	0	0	0	1.79	6.1	
Brown Sponge	21.70	25.32	40.00	1.71	11.73	40.00
Detritus						
Amorphous materials	0.74	0.29	10	0	0	0
Others						
Plastic fiber	0	0	0	0.52	0.03	10.00

The main food items for male *S. javus* in Davao Gulf were algae, seagrasses and zoobenthos (Table 4). The rarest prey items based on volume were the brown sponge, orange sponge and pieces of aluminum foil. Based on the frequency of prey items the ranking of preferred food items was *Kappaphycus> Gracilari sp.>Gelidiella sp.>Sargassum sp.* The prey items with the least frequency are the Brown sponges, Orange sponges pieces of aluminum foil, and *Cymodocea sp*. Bases on the percentage dry weight biomass of gut contents. *Gracilari sp.*, *Gelidiella sp.* and *Sargassum sp.* were the major food items that contribute to weight of gut contents in males.

For females, algae, zoobenthos and seagrasses were the main food items eaten in Davao Gulf (Table 4). The rarest prey items based on volume are orange sponges and *Kappaphycus sp*. Based on the frequency of prey items in the gut, the ranking of preferred food items was *Gelidiella>* brown sponges. The prey items with the least frequency were *Cymodocea sp.*, Gracilaria sp., Kappaphycus sp., orange sponges and amorphous materials. Based on the percentage dry weight biomass of gut, *Gelidiella sp.*, brown sponge and *Enteromorpha sp.*were the major food items that contribute to weight of gut contents of female *S. javus* from the Moro Gulf.

A summary of grouped prey items described by percentage volume and percentage by dry weight biomass are presented for female and male *S. javus* from all three bays (Table 5). Algae rank the most preferred food followed by zoobenthos (mostly sponges) and plants (mainly seagrasses). Similar results were observed for both sexes based on percentage by dry weight biomass.

Table 4

Gut content composition in *Siganus javus* from Davao Gulf showing indices of diet importance

Gut content composition	*Male*			*Female*		
	Volume (%)	*Biomass (%)*	*Frequency (%)*	*Volume (%)*	*Biomass (%)*	*Frequency (%)*
			Seagrass			
Cymodocea sp	10.26	10.16	11.11	4.63	16.67	16.67
			Algae - Red Algae			
Gelidiella sp	21.17	20.86	33.33	29.31	66.67	66.67
Gracilaria sp	25.22	24.06	44.44	6.41	16.67	16.67
Kappaphycus sp	6.53	8.29	55.56	2.78	16.67	16.67
Hypnea sp	3.09	1.54	11.11	0	0	0
			Green Algae			
Enteromorpha sp	11.96	10.41	22.22	0	0	0
			Brown Algae			
Sargassum sp	20.94	17.24	33.33	0	0	0
			Zoobenthos			
Orange sponge	1.85	7.24	11.11	1.85	16.67	16.67
Brown sponge	0.43	0.15	11.11	21.69	50.00	50.00
			Detritus			
Amorphous material	0	0	0	16.67	16.67	16.67
			Other			
Aluminum foil	0.31	0.06	11.11	0	0	0
Total	100	100	100	100	100	100

Table 5

Summary of grouped prey items based on percentage volume in *Siganus javus* samples collected from 3 locations in Mindanao, Philippines

Gut composition	*Percentage by volume*							
	Illana Bay		*Moro Gulf*		*Davao Gulf*		*Mean*	
	Male	Female	Male	Female	Male	Female	Male	Female
Plants	20	12.5	2.78	3.87	10.26	4.63	11.01	7.00
Algae	40	73.48	69.32	81.45	88.91	55.17	66.08	70.03
Zoobenthos	40	14.33	27.15	14.16	2.28	23.54	23.14	17.34
Detritus	0	0	0.74	0	0	16.67	0.25	5.56
Others	0	0	0	0.52	0.31	0	0.10	0.17
Total	100	100	100	100	100	100	100	100
	Percentage by dry weight biomass							
Gut composition	*Illana Bay*		*Moro Gulf*		*Davao Gulf*		*Mean*	*Mean*
	Male	Female	Male	Female	Male	Female	Male	Female
Plants	20	11.51	8.71	3.42	10.16	6.25	12.96	7.06
Algae	20	73.95	60.64	78.17	82.4	49.41	54.35	67.18
Zoobenthos	40	14.54	30.38	18.38	7.39	27.67	25.92	20.20
Detritus	0	0	0.29	0	0	16.67	0.10	5.56
Others	0	0	0	0.03	0.06	0	0.02	0.01
Total	100	100	100	100	100	100	100.00	100

Regarding measures of prey importance modified Pinkas Index of Relative Importance (IRI) values were computed based on combinations of three measures (volume, dry weight biomass, and frequency) (Table 6, Figure 4). For both sexes, higher IRI values were observed for most of the algae and sponges while Lower IRI values were observed for most of the detritus material and other materials such as plastic fibers, and some species in the plant category (*Halodule sp*.).

Table 6

Modified Pinkas Index of Relative Importance (IRI) of *Siganus javus* prey items from 3 sampling areas in Mindanao, Philippines

Gut composition	*Modified Pinkas Index of Relative Importance*					
	Illana Bay		*Moro Gulf*		*Davao Gulf*	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*
Plant - Seagrass						
Cymodocea	500	296.875	114.9	145.8	226.89	181.33
Halodule	0	0	0	98.36	0	0
Algae - Red Algae						
Gracilaria	0	0	1144.2	498	2190.22	183.5
Hypnea	0	1.125	0	0	51.44	0
Gelidiella	145.25	3901	402.2	368	1401	3781.33
Kappaphycus	0	58.25	1107	858.6	823.33	58.5
Mastophora	0.00	776.5	0	0	0	0
Green Algae						
Enteromorpha	1703.25	1796.5	33.7	1906.8	497.11	555.67
Brown Algae						
Sargassum sp	0	0	2310	1208	1272.67	0
Zoobenthos						
Gastropod	0.00	3	315.3	29.2	0	0
Amphipod	0	0.875	0	0	0	0
Orange sponges	2000	357	0	78.83	6.44	82.83
Brown sponges	0	0	1880.8	231.92	101	2312
Detritus						
Amorphous materials	0	0	10.3	0	0	555.67
Others						
Plastic Fibers	0	0	0	5.55	0	0
Aluminum foil	0	0	4.11	0	0	

Graphical presentation summarizing measures of prey importance is presented in figure 5. Prey items that occupy a large space in the graphical representations are said to be important. Of note, percentage volume of prey items does not necessarily mean that values are parallel to dry weight biomass (Gorospe & Demayo 2008). Sponges in the prey items of *S. javus* for example have higher density compared to other prey items that have large and variable water content.

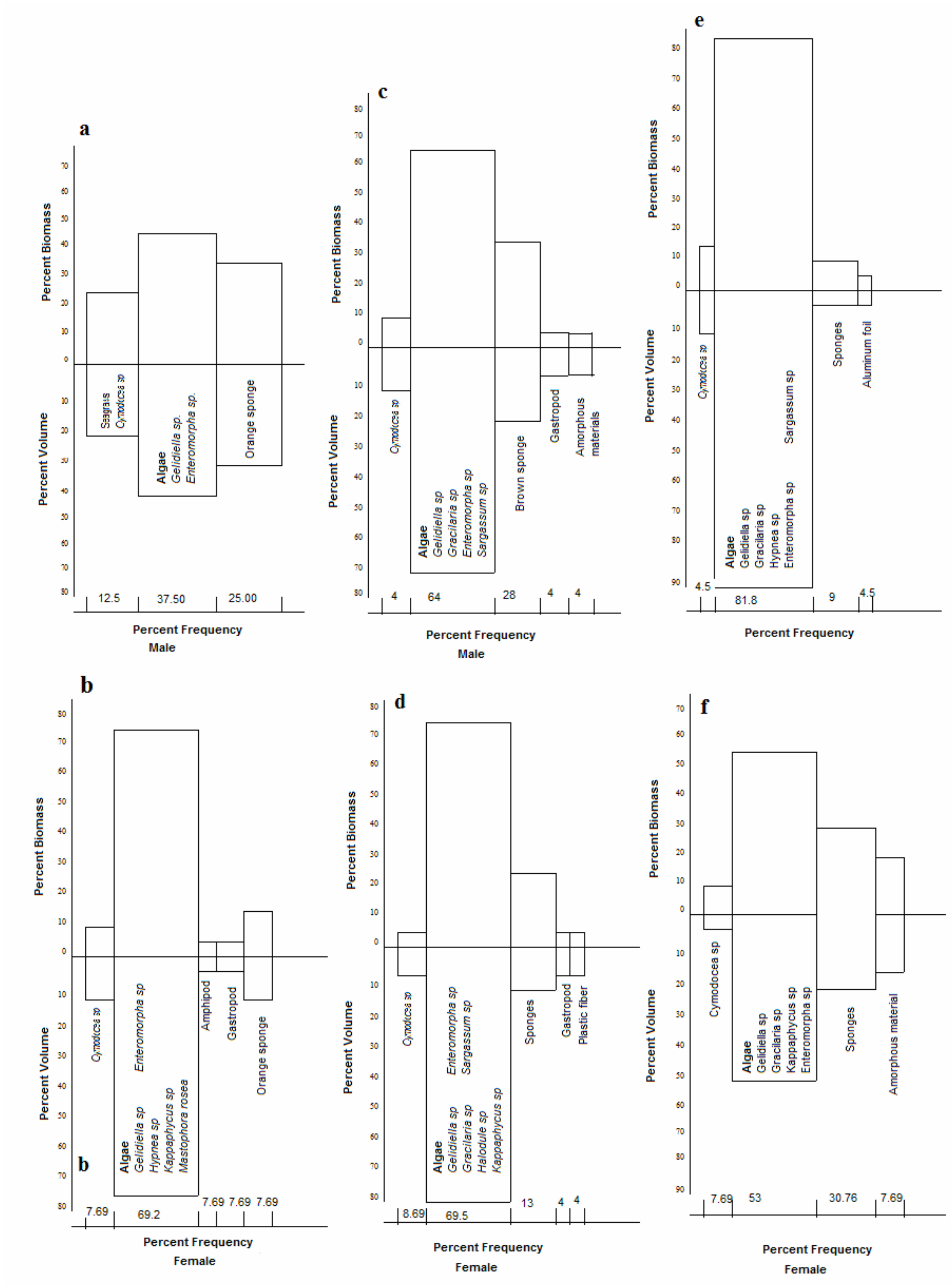

Figure 4. A modified Index of Relative Importance (IRI) of the prey items showing their corresponding biomass, volume, and frequency values of *Siganus javus* male and female samples in (a, b) Illana Bay, (c, d) Moro Gulf, (e, f) Davao Gulf.

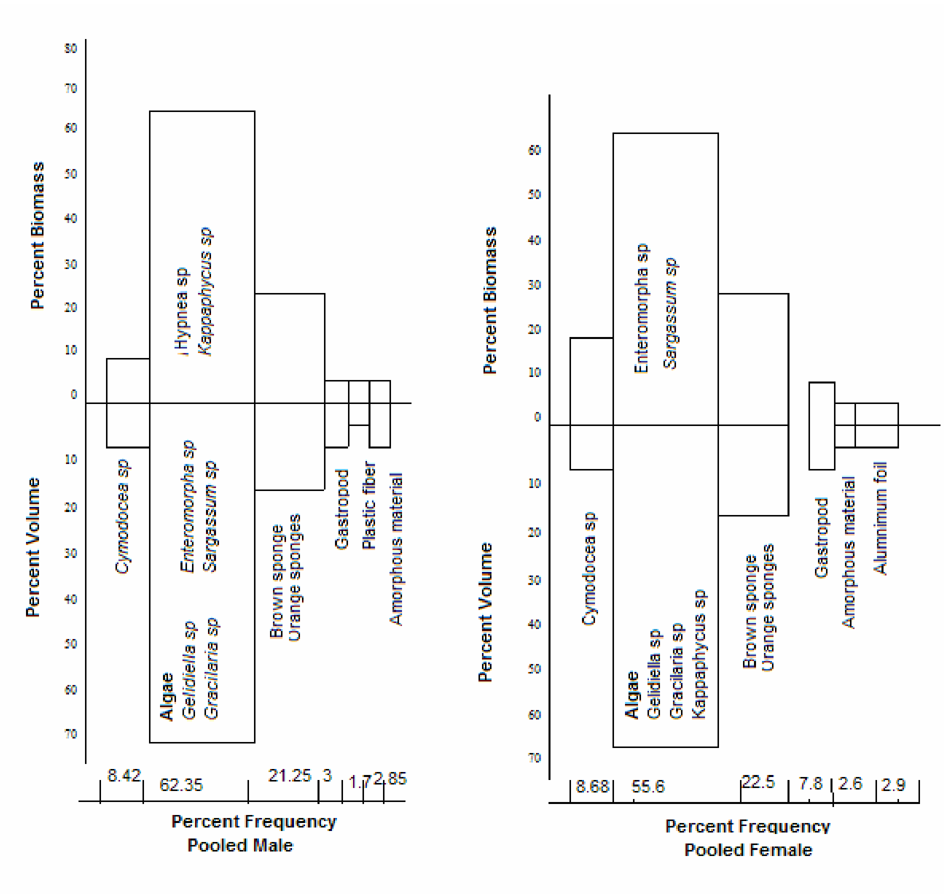

Figure 5. A modified Index of Relative Importance (IRI) of the prey items showing their corresponding biomass, volume, and frequency values. Prey items are not ranked but in the order of prey items of pooled *Siganus javus* male and female.

Costello method is also employed to measure prey importance and feeding strategy of *S. javus.* Results show the feeding strategy of *S. javus* implies a trophic specialist omnivore feeding mostly on algae but also fed on sponges and seagrasses including minute amounts of gastropods and detritus, amphipods, univalves ingested (Figure 6).

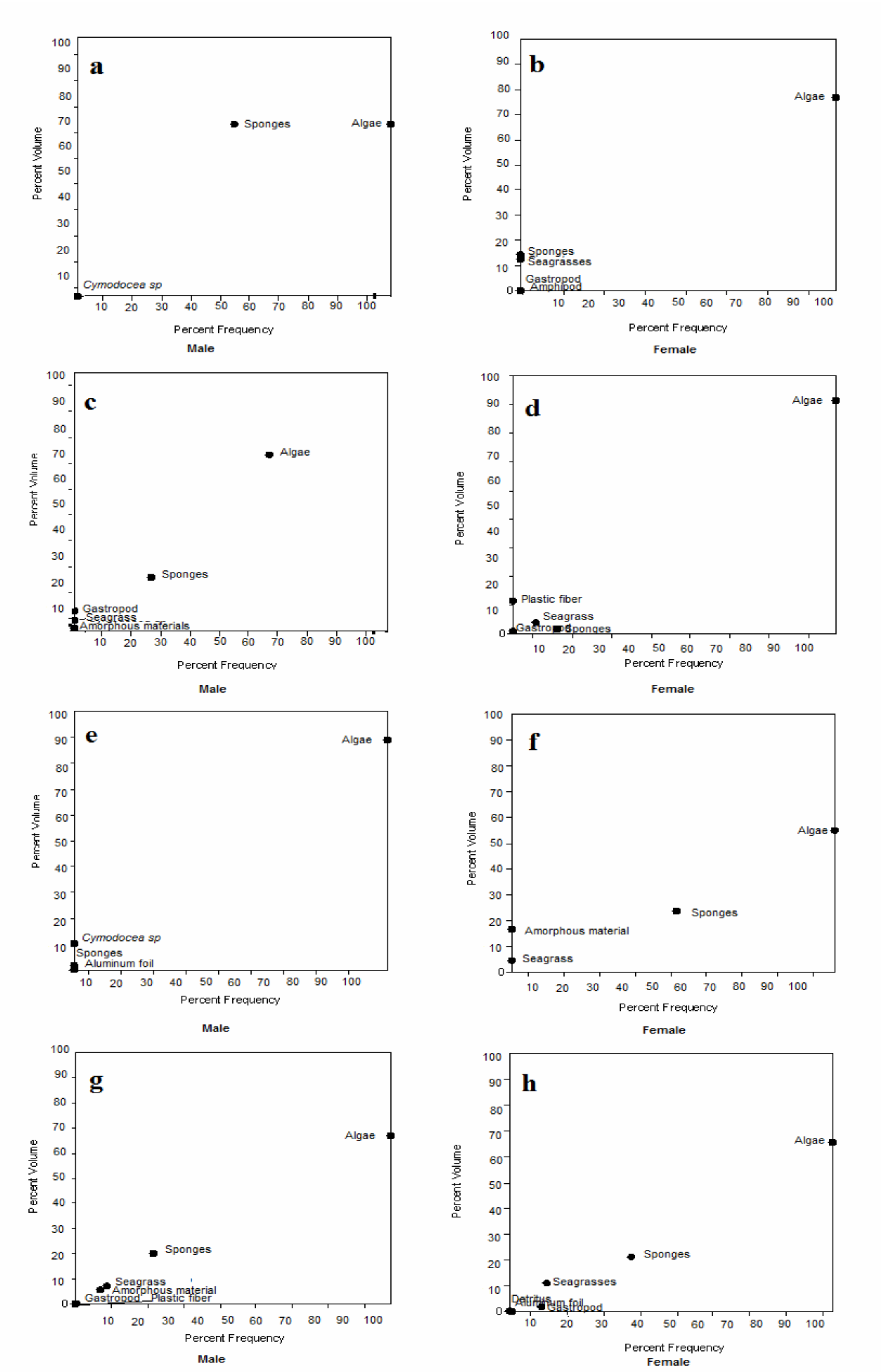

Figure 6. Prey importance and feeding strategy of *Siganus javus* male and female from (a, b) Illana Bay, (c, d) Moro Gulf, (e, f) Davao Gulf, (g, h) pooled data based on Costello's method.

Conclusions. The results of this study show that variations in gut content within and between populations indicate that feeding habits of the fish could be influenced by the availability of food sources and maybe on the opportunistic feeding behavior of the species. Many studies conducted analyzing the gut content of other species of Siganids showed that the algae preferred by captive fish were not always those found in greatest quantity in the gut. Studies conducted on juveniles and adult *S. spinus*, juveniles of *S. argenteus*, *S. guttatus*, *S. virgatus*, and *S. canaliculatus* prefer *Enteromorpha sp.* in the laboratory but take this only in small amounts in nature (Tsuda & Bryan 1973; Subandiyono 2001). Aside from algal food, they can also feed accidentally on some non-digestible substances such as mollusk shells and other invertebrates attached to algae (Sabour & Lakkis 2007). In addition, these species were reported to consume seagrass (e.g. *Enhalus sp*., *Padina sp*., *Gelidium* and *Sargassum halophyla*) or filamentous algae in the wild, whereas in captivity, they take any types of food including seagrass, filamentous algae, fish meals, shrimp meals, cassava flour, or pelleted diet (Subandiyono 2001).

In the present study conducted, *S. javus* ingests mostly algae, particularly the red algae than seagrass or zoobenthos in all three bays. The presence and preference of algae in the gut of most *S. javus* individuals means that this species inhabits along reef edges where species of red algae are usually present and that they often come also into intertidal zones to feed on other types of algae and on seagrasses and sponges. The ingestion of plastic fibers maybe due to semblance to red algae or they are soft like algae thus may have been feed upon by *S. javus* too. The ingestion of amphipods could be explained as these are epifaunal inhabitants in seagrass and so when *S. javus* feeds upon seagrass or algae these were also ingested in (Klumpp & Kwak 2005; Gorospe & Demayo 2008). Similar results were obtained from a related study conducted on the diet of *S. rivulatus* and *S. luridus* (species within the same family but an introduced species in the eastern Mediterranean seas) which show that while these two species are selective when macrophytes are diverse and present in large quantities will eat what is available (Bariche 2006). Gorospe & Demayo (2008) also showed in the diet of *S. guttatus* from Northern Mindanao, Philippines, are mostly seagrasses over algae; and in one particular location, the species even ingest detritus more so than seagrasses or algae. These findings just show that the diet of *Siganus* fishes are usually on the availability of the resources in different habitats *S. javus* included. As revealed in this study, *S. javus*' feeding strategy is more of a trophic specialist omnivore with a preference for plant material but also capable of feeding on other prey such as sponges, seagrass, and amphipods as these prey items are available.

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