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# **Reproduction and community structure of fish from winter shrimp bycatch from the Southeast Gulf of California**

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Shrimp fishery is one of the most important fisheries of the world. However, the low selectivity from trawl nets leads the capture of a large number of non-target species. Shrimp bycatch include a large number of fish and invertebrate species; of which fish species are the most abundant. The present study aims to determine the community structure as well as the average sizes at first maturity of the fish species from shrimp bycatch caught from industrial fisheries at the southeast of the Gulf of California from Sinaloa to Guerrero, Mexico; from January to March 2015. A total of 37 species of finfish were found; of which five were considered rare. The fish species with the highest Importance Value Index (IVI) were *Pseudupeneus grandisquamis*, *Paralichthys woolmani*, *Lutjanus peru* y *Diapterus peruvianus*. The average size at first maturity of 12 fish species was determined; nine of which have not been previously reported. Of the analyzed organisms 90% were in juvenile stage; including species with riverine and artisanal fisheries. The present study demonstrates the risk in marine populations of different non-target species due to the low selectivity of shrimp trawls.

- 1 Reproduction and community structure of fish from winter shrimp bycatch from the
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#### 17 Abstract

- 18 Shrimp fishery is one of the most important fisheries of the world. However, the low selectivity
- 19 from trawl nets leads the capture of a large number of non-target species. Shrimp bycatch include
- 20 a large number of fish and invertebrate species; of which fish species are the most abundant. The
- 21 present study aims to determine the community structure as well as the average sizes at first
- 22 maturity of the fish species from shrimp bycatch caught from industrial fisheries at the southeast
- of the Gulf of California from Sinaloa to Guerrero, Mexico; from January to March 2015. A total
- of 37 species of finfish were found; of which five were considered rare. The fish species with the
- 25 highest Importance Value Index (IVI) were *Pseudupeneus grandisquamis*, *Paralichthys*
- 26 woolmani, Lutjanus peru y Diapterus peruvianus. The average size at first maturity of 12 fish
- 27 species was determined; nine of which have not been previously reported. Of the analyzed
- organisms 90% were in juvenile stage; including species with riverine and artisanal fisheries.
- 29 The present study demonstrates the risk in marine populations of different non-target species due
- 30 to the low selectivity of shrimp trawls.
- 31 Key words. Community structure, Length of maturity, Finfish, Shrimp bycatch.

#### 32

#### 33 Introduction

- 34 Shrimp are among the most globally traded fishery products. The shrimp fishery generates
- 35 important economic benefits. Nevertheless, there has been a constant emphasis on the impact of
- this activity on shrimp bycatch fauna; FAO considers this fishery the main source of discards
- 37 (Kumar and Deepthi, 2006; FAO, 2017). At global level constant proposals and innovations have
- been made for the design of trawls (Boopendranath et al, 2013), making a great progress in the
- 39 protection of sea turtles and sea mammals (Morzaria-Luna et al, 2013). However, species
- 40 considered as minor importance died during the trawling, and these organisms are returned to the
- 41 sea; leads to environmental contamination (Ramírez-Ramírez et al, 2008).
- 42 In tropical countries shrimp bycatch corresponds to more than 90% of the catch; some of these
- 43 organisms with a greater marketing potential. Nevertheless, biological aspects from shrimp
- 44 bycatch fish are scarce (Ramos-Santiago et al, 2006; Herrera-Valdivia, López-Martínez and
- 45 Morales-Azpeitia, 2016). In addition to knowing the species of fish that comprise the bycatch, it
- is important to know their size structure and reproductive status, because a large part of shrimp
- 47 bycatch organisms correspond to juveniles, or sub adults, which significantly affects recruitment
- 48 for the following generations (Broadhurst et al, 2000). The lack of information about the size of
- 49 first maturity, reproductive periods, as well as the minimum sizes of catch, lead an absence of a
- 50 correct regulation of small fisheries (Morzaria-Luna et al, 2013).
- 51 Therefore, the aim of this work is to determine the population structure and relative abundance of
- 52 the fish species present in the accompanying fauna of the shrimp, as well as their spatial
- variability and potential risk in the recruitment of species. Such information is the basis for
- 54 determining the actual status of marine communities and the effect of human activity in each
- 55 region.
- 56

#### 57 Materials and methods

- 58 This study is based on analysis of bycatch obtained from trawling of a shrimp vessel operating
- 59 on the continental shelf from Sinaloa to Guerrero; southeast of the Gulf of California. The work
- 60 included the fauna obtained from seven catch sites (Fig. 1; Table 1). The catches were made
- from January 26 to March 20, 2015, using a trawl of 70' feet long (21.3 m) and 37 mm net mesh.
- Each trawl was submerged for two hours at a depth of 20 and 54 meters approximately.
- 63 After the target species (shrimp) was separated at the vessel, a random sample of 10 kg from
- bycatch fauna was taken, from which all finfishes species were separated and identified to
- 65 species level (Allen and Robertson, 1994). The Total Length (TL) of each organism was

- 66 measured and gonadal maturity and sex was analyzed by morph-colorimetric methods (Bucholtz,
- 67 Tomkiewicz, and Dalskov, 2008; Sánchez et al, 2013).
- Total abundance and abundance per station of each species was estimated. Besides, the Relative
- 69 Density (RD), Relative Frequency and Importance Value Index (IVI; Smith and Smith, 2006)
- 70 were calculated for each species; which indicates the degree of dominance of one or more
- 71 species and their degree of constancy within the ecosystem.

$$RD = \frac{\text{Total number of individuals of a species}}{\text{Total number of individuals of all species}} X 100$$

 $FA = \frac{Frequency of one species}{Total frequency of all species} X 100$ 

73

72

IVI = RD + FR

75 The 12 species with the highest IVI were selected for the evaluation of the size structure per

- station. The sizes of the organisms were analyzed to determine the normality and
- homoscedasticity of the sample. A one-way ANOVA at p < 0.05 was used to find significance
- between the data, and finally the differences among stations were sought by the Tukey-Kramer
- multiple comparison test, with a 95% confidence level with the support of the NCSS 2007
- 80 statistical program.

#### 81 <u>Length at maturity (TL<sub>m</sub>)</u>

In the literature, information on sexual maturity comes in various categories "concepts" (Froese and Pauly 2000), symbols and definitions (Ragonese and Bianchini 2014), closely related. The

84 mean length at which fish of a given populations become sexually mature for the first time  $(L_m)$ 

is an important management parameter used to monitor whether enough juveniles in an exploited

stock mature and spawn (Beverton and Holt, 1959; Ault, Bohnsack and Meester, 1998; Jennings, Reynolds and Mills, 1998). To facilitate estimation of  $L_m$  in absence of suitable data, an empirical

- relationship based on linking  $L_m$  with  $L_\infty$  was used and proposal by Froese and Binohlan (2000).
- 89  $\log L_{\infty} = 0.044 + 0.9841 * \log(TL_{max})$
- 90  $logTL_m = 0.8979*log(L_{\infty})-0.0782$
- 91  $TL_{max}$  was obtained for each species in the sample of FishBase.org.

92

- 93 **Results**
- 94 Fish relative abundance and distribution

- From the seven stations, the highest specific richness was at station 7 with 17 species, while the
- lowest specific richness was presented at station 4 with 13 species (Fig. 2). The total abundance
- of the study was 1410 fish from 37 species, belonging to 28 families and 35 genera. Rare species
- were only found in one station and corresponded to 16% of fish species (table 2).
- 99 Of the 37 fish species, only 13 species had an IVI greater than 50. The most frequent species
- 100 were the bigscale goatfish *Pseudupeneus grandisquamis*, speckled flounder *Paralichthys*
- 101 *woolmani*, Pacific red snapper *Lutjanus peru* and the Peruvian mojarra *Diapterus peruvianus*
- 102 (Table 2); the four presented the greatest abundances of the study with 398, 327, 213 y 126
- 103 individuals, respectively. Meanwhile the rare species were *Bagre pinnimaculatus, Bairdiella*
- 104 ronchus, Brotula clarkae, Ancylopsetta dendrítica y Sphyraena guachancho with only one
- 105 individual of each species throughout the study.
- 106
- 107 <u>Community structure</u>
- 108 From the 12 fish species with higher IVI, just P. grandisquamis (IVB= 128.15), P. woolmani
- 109 (IVB= 122.63), *L. peru* (IVB= 115.06) and *D. peruvianus* (IVI= 108.91) were present at all
- stations (Table 3), with maximum abundances per station of 197, 96, 91, 49 individuals,
- 111 respectively. The rest of the species were absent in at least one station, with an average
- abundance among 2 and 10 individuals per station.
- 113 In the majority of species, no significant differences were found in the TL size structure
- according to the latitudinal distribution; only *Synodus scituliceps* showed highly significant
- differences (p < 0.01) in station 1 relative to station 2 (Fig. 3). The average sizes from *D*.
- 116 peruvianus, L. peru, P. woolmani and P. grandisquamis were 12 cm, 12.71 cm, 11.51 cm, 12.11
- 117 cm, respectively.
- 118 Fish sex proportion and sexual maturity.
- 119 The  $TL_m$  for the species with highest IVI was 18.5 cm for *P. grandisquamis* and *D. peruvianus*,
- 120 44 cm for *P. woolmani* and 51.2 cm for *L. peru* (Fig. 3). For all analyzed species, less than 10%
- 121 of fish presented developed gonads (Fig. 4); only the species *Scorpaena sonorae* presented a
- 122 100% of mature individuals; although individuals from this species were only found at station 6.
- 123 The absence of developed gonads did not allow the sex determination from 23 of the 37 fish
- species analyzed. From the remaining 14 species, 90% of the organisms were female and only
- 125 males were found in three species: *Diplectrum macropoma*, *D. peruvianus* and *Larimus*
- 126 *argenteus*; in the last one, the proportion of males was greater than females with 75% (Fig. 5).
- 127

#### 128 Discussion.

- 129 The shrimp bycatch in Mexico, as in tropical countries, is composed of a great diversity of
- 130 species of mollusks, echinoderms, crustaceans and fish. All fish species analyzed in this study

- belong to superclass Osteichthyes. Although a large number of rare and low frequent species
- 132 were found at each station, however, great abundances were also founded as is the case of P.
- 133 *grandisquamis* with 197 individuals in a 10 kg sample. The species of fish found within the
- accompanying fauna of the shrimp are typical of sandy substrates of lagoon-estuarine systems
- where shrimp fishery is carried out (Rábago-Quiroz et al, 2011), with the exception of species
- 136 associated with rocky and coral environments like Chaetodon humeralis and Balistes polylepis,
- both were considered as rare species; where specifically *C. humeralis* was only found at station
- 138 7.
- 139 The most representative families of this study (Sciaenidae, Tetraodontidae, Haemulidae and
- 140 Paralichthyidae, among others) are typical of captures of tropical regions (Gibinkumar et al.,
- 141 2012). Although only 38% of the species were considered abundant and frequent, suggesting that
- 142 most species were caught during the haul or lifting of the net. The great majority of analyzed
- species corresponded to benthopelagic species (*Caranx otrynter*, *Chloroscombrus orqueta*, *S.*
- 144 pachygaster, Isopisthus remifer) and pelagic-neritic species (Fistularia corneta, L. argenteus and
- 145 *Opisthonema libertate*), which coincides with previous reports of studies for the Gulf of
- 146 California (López-Martínez et al, 2010; González-Sansón et al, 2014).
- 147 The dominant species of the study; with an IVI greater than 50, contribute with more than 92%
- 148 of the total abundance, which is typical of catches in the Gulf of California (Rábago-Quiroz et al,
- 149 2011). It has even been reported that by-catch may have larger volumes than the target fishery
- 150 (Barreto, Polo and Mancilla, 2001, Gibinkumar et al., 2012). On the other hand, the analyzed
- 151 organisms presented a great variety of sizes classes; mostly below 20 cm TL and mainly juvenile
- 152 organisms. These sizes agree with previous reports indicating that organisms in this size class are
- more likely to be stuck in hauls, because the effort to escape from the nets is too exhausting
- 154 (Liggins and Kennelly, 1996).
- 155 From the above, it is necessary to seek strategies for the management and use of these species,
- since the vast majority of species have a high potential for commercialization, and even several
- 157 of these species have their own fisheries (FAO, 2017). One of the three fisheries indicators is the
- 158 percentage of mature fish in catch; especially to assess an eventual risk in fish stocks (Froese,
- 159 2004). In general for teleosts, the use of maximum length to predict the length at first maturity
- 160 was probed (Froese and Binohlan, 2000); as in seahorses species, for example (Foster and
- 161 Vincent, 2004), due the asymptotic length is highly correlated with maximum length.
- 162 The correlation among asymptotic length and first maturity length was of 85-91% across 265 fish
- species (Froese and Binohlan, 2000). However, for the most part of the species, there are no
- 164 reports on many of its biological aspects; highlighting only studies of species A. mazatlanus, L.
- 165 peru, P. woolmani and P. grandisquamis (Amezcua-Linares and Castillo-Rodriguez, 1992;
- 166 Ramos-Santiago et al, 2006; Herrera-Valdivia, López-Martínez and Morales-Azpeitia, 2016;
- 167 FishBase, 2017). In this sense, it is important to emphasize that both first maturity sizes and
- 168 reproductive periods are not static, but are subject to environmental variations and the analysis

- 169 methods (Rodríguez-Domínguez et al, 2015). Usually the size at first maturity is underestimated.
- 170 For teleosts, the size at first maturity is estimated as the size at which 50% of the organisms have
- reached sexual maturity, the size at which ovaries appeared (Kanou and Kohno, 2001), the size
- of the smallest recorded female with hydrated eggs (Nguyen and Do, 1996), the size of the
- smallest recorded first bred, and the minimum size of the recorded female to release her eggs
- 174 (Froese, 2004).
- 175 The present study is the first to analyze the sizes at first maturity of fish species present in shrimp
- bycatch, including inferring or direct methods; of which, more than 90% of the organisms are
- 177 outside the limits of sustainable fisheries, that is, well below the size of first maturity (immature
- 178 organisms). However, none of the species analyzed in this study presents a hazard status or are
- threatened according to conservation standards (NOM-ECOL-059-2010; COFEMER, 2017;
- 180 CONABIO, 2017), this may be due to the scarcity of population and reproductive studies.
- 181 Although, some species have well established fisheries (*L. peru* y *P. woolmani*) there is no
- 182 official regulation on minimum catch sizes; only a minimum catch size has been proposed for *L*.
- *peru* at 31 cm TL (Ramos-Cruz, 2001; COMEFER, 2017). This study shows that many of the
- 184 species present in shrimp bycatch have an imminent risk, due to their low sizes at catch and the
- 185 large percentage of immature organisms within the catches, which not only affects the
- 186 populations, but also damages to the whole trophic chain.

#### 187 Conclusions

- 188 From the Southeast Gulf of California winter shrimp bycatch a total of 37 fish species were
- identified; of which, dominant species were *P. grandisquamis*, *P. woolmani*, *L. peru* y *D*.
- 190 *peruvianus*. From analized organisms, 90% were in juvenile stage; meanwhile, from the group
- 191 with developed gonad, 93% were female. This work highlights the necessity to improve the
- selectivity from the shrimp trawls and the imminent risk for the marine communities.

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## Figure 1

Location of the seven shrimp catches stations in the Southeast of Gulf of California, México.



## Figure 2

Species richness of fishes from shrimp bycatch per sampled station



### Figure 3

Fishes size structure at each sampling station

A) A. mazatlanus. B) C. orqueta. C) D. peruvianus. D) D. macropoma. E) F. corneta. F) L. peru. G) P. woolmani. H) P. panamensis. I) P. horrens. J) P. grandisquamis. K) S. pachygaster. L) S. scituliceps. The bars represent the average total length  $\pm$  standard deviation. The dotted gray line indicates the size of first maturity reported in the literature. The continuous gray line indicates the average length of maturity obtained in this study. The dotted black line indicates the maximum size of immature organisms obtained during this study. \* Represents significant differences in total length from each species among different sampled stations (p<0.01).

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S. scituliceps

### Figure 4

#### Juvenile and mature fish's proportion

Ma: mature (developed gonad). Im: immature (undeveloped gonad). Bars represent 100% of organisms. Gray bar: percentage of immature individuals. Black bar: percentage of mature individuals.



### Figure 5

Sex proportion of fishes from shrimp bycatch

F: female. M: male. Bars represent 100% of organisms. Gray bar: percentage of females. Black bar: percentage of males.



#### Table 1(on next page)

Geographic location of each of the stations sampled at the SE of the Gulf of California.

|            | Lat.<br>North | Long West  | Depth (m) | Day sampling period |  |  |
|------------|---------------|------------|-----------|---------------------|--|--|
| <b>S</b> 1 | 22.44390      | -106.02915 | 30.6      | Day                 |  |  |
| S2         | 22.27755      | -106.55704 | 37.8      | Night               |  |  |
| S3         | 22.24762      | -105.50341 | 37.8      | Day                 |  |  |
| S4         | 22.21147      | -105.50131 | 32.4      | Day                 |  |  |
| S5         | 22.05882      | -105.51375 | 34.2      | Night               |  |  |
| <b>S</b> 6 | 21.48749      | -105.42990 | 27        | Day                 |  |  |
| <b>S</b> 7 | 16.40722      | -99.42970  | 19.8      | Day                 |  |  |
|            |               |            |           |                     |  |  |

1 Table 1. Geographic location of each of the stations sampled at the SE of the Gulf of California.

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#### Table 2(on next page)

Table 2. Fishes IVI from shrimp bycatch from the southeast of the Gulf of California.

RD: Relative Density, RF: Relative Frequency, IVI: Importance Value Index; from highest to lowest IVI. Freq: Frequency; R: Rare, LF: Low frequent, F: Frequent, HF: High Frequent.  $TL_{max}$ : Maximum length.  $TL_m$ : Length of maturity. SL: Standard length. FL: Fork length.

- 1 Table 2. Fishes IVI from shrimp bycatch from the southeast of the Gulf of California.
- 2 RD: Relative Density, RF: Relative Frequency, IVI: Importance Value Index; from highest to lowest IVI.
- 3 Freq: Frequency; R: Rare, LF: Low frequent, F: Frequent, HF: High Frequent.  $TL_{max}$ : Maximum length.
- 4 *TL<sub>m</sub>*: Length of maturity. SL: Standard length. FL: Fork length.

|                 |                            |      |       |       |        | TL <sub>max</sub> | TL <sub>m</sub> |
|-----------------|----------------------------|------|-------|-------|--------|-------------------|-----------------|
| Family          | Specie                     | Freq | RD    | RF    | IVI    | (cm)              | (cm)            |
| Mullidae        | Pseudupeneus grandisquamis | HF   | 28.15 | 100   | 128.15 | 30                | 18.5            |
| Paralichthyidae | Paralichthys woolmani      | HF   | 22.63 | 100   | 122.63 | 80                | 44              |
| Lutjanidae      | Lutjanus peru              | HF   | 15.06 | 100   | 115.06 | 95                | 51.2            |
| Gerreidae       | Diapterus peruvianus       | HF   | 8.91  | 100   | 108.91 | 30                | 18.5            |
| Tetraodontidae  | Sphoeroides pachygaster    | HF   | 5.16  | 85.71 | 90.87  | 40.5 SL           | 24.1 SL         |
| Haemulidae      | Pomadasys panamensis       | HF   | 4.81  | 85.71 | 90.52  | 39                | 23.3            |
| Carangidae      | Chloroscombrus orqueta     | HF   | 1.13  | 85.7  | 86.83  | 30                | 18.5            |
| Synodontidae    | Synodus scituliceps        | F    | 2.26  | 71.42 | 73.68  | 42                | 24.9            |
| Triglidae       | Prionotus horrens          | F    | 0.85  | 71.42 | 72.27  | 35                | 21.2            |
| Fistulariidae   | Fistularia corneta         | F    | 0.78  | 71.42 | 72.2   | 106               | 56.3            |
| Serranidae      | Diplectrum macropoma       | F    | 2.83  | 57.14 | 59.97  | 18                | 11.7            |
| Achiridae       | Achirus mazatlanus         | F    | 0.28  | 57.14 | 57.42  | 20                | 12.9            |
| Batrachoididae  | Nautopaedium porosissimum  | F    | 0.24  | 57.14 | 57.42  | 32                | 19.5            |
| Ophichthidae    | Ophichthus triserialis     | F    | 0.28  | 42.85 | 43.13  | 122               | 63.8            |
| Balistidae      | Balistes polylepis         | LF   | 0.21  | 42.85 | 43.06  | 76                | 42              |
| Sciaenidae      | Larimus argenteus          | LF   | 0.21  | 42.85 | 43.06  | 35                | 21.2            |
| Carangidae      | Selene brevoortii          | LF   | 0.85  | 28.57 | 29.42  | 38 FL             | 22.8 FL         |
| Ophidiidae      | Lepophidium prorates       | LF   | 0.42  | 28.57 | 28.99  | 29.5 SL           | 18.2 SL         |
| Sciaenidae      | Isopisthus remifer         | LF   | 0.35  | 28.57 | 28.92  | 36                | 21.7            |
| Clupeidae       | Opisthonema libertate      | LF   | 0.28  | 28.57 | 28.85  | 30                | 18.5            |
| Carangidae      | Caranx otrynter            | LF   | 0.21  | 28.57 | 28.78  | 60                | 34.1            |
| Bothidae        | Bothus constellatus        | LF   | 0.14  | 28.57 | 28.71  | 15.7              | 10.4            |
| Cynoglossidae   | Symphurus prolatinaris     | LF   | 0.14  | 28.57 | 28.71  | 16.1 SL           | 10.6 SL         |
| Carangidae      | Trachinotus kennedyi       | LF   | 0.14  | 28.57 | 28.71  | 90                | 48.8            |
| Tetraodontidae  | Sphoeroides testudineus    | LF   | 1.27  | 14.28 | 15.55  | 38.8              | 23.2            |
| Polynemidae     | Polydactylus opercularis   | LF   | 0.92  | 14.28 | 15.2   | 50                | 29              |
| Scorpaenidae    | Scorpaena sonorae          | LF   | 0.42  | 14.28 | 14.7   | 15.8 SL           | 10.5 SL         |
| Tetraodontidae  | Sphoeroides annulatus      | LF   | 0.21  | 14.28 | 14.49  | 44                | 25.9            |
| Chaetodontidae  | Chaetodon humeralis        | LF   | 0.21  | 14.28 | 14.49  | 25.4              | 15.9            |
| Engraulidae     | Anchoa walkeri             | LF   | 0.21  | 14.28 | 14.49  | 14.5              | 9.7             |
| Gobiidae        | Bollmannia stigmatura      | LF   | 0.14  | 14.28 | 14.42  | 14 SL             | 9.4             |
| Haemulidae      | Xenichthys xanti           | LF   | 0.14  | 14.28 | 14.42  | 24                | 15.2            |
| Ariidae         | Bagre pinnimaculatus       | R    | 0.07  | 14.28 | 14.35  | 95                | 51.2            |
| Sciaenidae      | Bairdiella armata          | R    | 0.07  | 14.28 | 14.35  | 30                | 18.5            |
| Bythitidae      | Brotula clarkae            | R    | 0.07  | 14.28 | 14.35  | 115               | 60.6            |
| Paralichthyidae | Ancylopsetta dendritica    | R    | 0.07  | 14.28 | 14.35  | 35                | 21.2            |
| Sphyraenidae    | Sphyraena guachancho       | R    | 0.07  | 14.28 | 14.35  | 200               | 98              |

### Table 3(on next page)

Abundance per station of fish species with highest IVI

| Species          | <b>S1</b> | <b>S2</b> | <b>S3</b> | <b>S4</b> | <b>S5</b> | <b>S6</b> | <b>S7</b> |
|------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| C. orqueta       | 1         | 2         | 1         | 3         | 6         |           | 3         |
| D. peruvianus    | 13        | 9         | 3         | 15        | 49        | 26        | 11        |
| D. macropoma     | 8         | 6         |           |           | 3         | 23        |           |
| F. corneta       | 1         | 5         |           | 2         | 2         |           | 1         |
| L. peru          | 21        | 61        | 11        | 91        | 8         | 7         | 14        |
| P. woolmani      | 24        | 24        | 44        | 22        | 36        | 74        | 96        |
| P. panamensis    | 7         | 9         | 3         | 2         | 13        | 34        |           |
| P. horrens       | 1         | 6         | 2         | 1         |           |           | 2         |
| P. grandisquamis | 67        | 31        | 19        | 36        | 12        | 36        | 197       |
| S. pachygaster   | 6         | 5         | 36        | 6         |           | 17        | 3         |
| S. scituliceps   | 2         | 2         |           |           | 6         | 17        | 5         |

1 Table 3. Abundance per station of fish species with highest IVI.

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