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Annals of Aquaculture and Research

Short Communication

Incidental Catch of Mollusks Associated with Shrimp Fishery in the Gulf of Tehuantepec, Southern Mexican Pacific

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Submitted: 01 August 2016

Accepted: 26 August 2016

Published: 28 August 2016

ISSN: 2379-0881

Keywords

- By-catch
- Shrimp fishing
- Environmental Impact
- Mollusks
- Mexican Pacific

Abstract

This study presents the species of bivalves and gastropods of commercial interest and potential use recorded in 33 sampling stations in the Gulf of Tehuantepec, southern Mexican Pacific. The collections were performed with a trawling net on board of the shrimp vessel FIPESCO 63. The relative abundance and the biological value index (BVI) of every species was calculated as an indicator of the importance of the mollusks based on the abundance and frequency of the species in the samples. A total of 832 individuals of 59 species (18 bivalves, 41 gastropods) from which most are of commercial or potential interest. The most abundant were *Argopectenirradians*, *Harpacrenata*, *Granolariasalmo*, *Ficusventricosa*, *Crepidulaexcavata*, *Hexaplexbrassica*, *Malearingens*, *Crucibulumlignarium*, *Fusinusdupetitthouarsi*,*Tonna* sp., *Olivasplendidula*, *Melongenapatula*, *Conuspatricius* and *Crucibulumpersonatum*. Comments and suggestions are made on the present use of the species and the possibilities of exploitation in aquaculture and fishery taken into consideration previous experiences with these and other species in different regions of the Mexican Pacific and the rest of the world.

ABBREVIATIONS

BVI: Biological Value Index; TI: Total number of Individuals collected from all samples; RA: Relative Abundance; ARA: Accumulative Relative Abundance

INTRODUCTION

Incidental catch of non-target species has been a major concern because there are many associated environmental impacts and socio-economic issues including the capture of juveniles of ecologically important and economically valuable species, coastal habitat degradation, illegal trawling and conflicts between artisanal and industrial fisheries. It has been estimated that one quarter of the total catch of the world fisheries is discarded annually [1]. Shrimp fishing, especially trawling in tropical regions, produces large amounts of by-catch that is discarded causing a major impact on benthic populations. By-catch usually refers to non-target captured organisms, which are retained for sale or use, while discards are unusable or unwanted ones that are thrown back to sea because of either low value or regulatory requirements [2]. Shrimp by-catch often includes not only the juveniles of important commercial fish species but also shellfish (crustaceans and mollusks) most of which are discharged. Recently, Davis et al., [3] remarked the importance of redefining the term by-catch because perceptions of target and non-target catch vary widely, impeding efforts to estimate by-catch globally. They propose a new definition as "By-catch is catch that is either unused or unmanaged". According to this definition, unused catch is that which is not used for consumption, sold for any purpose, or reused by the fisher as bait. It includes discards (that portion of the catch that is thrown overboard) and wasted catch after landing that is neither sold nor directly consumed. The unmanaged refers to catch, whether categorized as individual species or groups of different species that does not have specific management to ensure the take is sustainable. Applying this definition to global marine fisheries data conservatively indicates that by-catch represents 40.4 % of global marine catches, exposing systemic gaps in fisheries policy and management. Quantification of the unused or unmanaged catches give a better approximation of how much by-catch is being retained and which fisheries are causing the greatest impacts, thereby allowing an understanding of the effect this biomass removal is having on the marine environment. Shrimp fishing in Mexico takes place in the Pacific, Gulf of Mexico and Caribbean, by both artisanal and industrial fleets. A vast number of small fishing vessels use many types of gear to catch shrimp.

The larger offshore shrimp vessels, numbering about 2,212 traw using either two nets (Pacific side) or four nets (Atlantic side). In 2003, shrimp production in Mexico of 123,905 t came from three sources: 21.26 % from artisanal fisheries, 28.41 % from industrial fisheries and 50.33 % from aquaculture activities. Shrimp is the basis of the most important fishery commodity in Mexico in terms of value, exports and employment. Catches of Mexican Pacific shrimp appear to have reached their maximum. It is generally recognized that overcapacity is a problem in the various shrimp fleets [4-6]. The National Fisheries Institute of Mexico carried out a series of studies on by-catch from 1956. Results were reported by Rosales [7], Chávez and Arvizu [8], Chapa [9], Grande-Vidal and Díaz [10], Corripio [11], and Grande-Vidal [12-15]. These studies showed that 60–63% of the by-catch from the shrimp fishing fleets on both coasts was composed of various species of fish, with the remainder being crustaceans, mollusks and echinoderms. The authors found that the proportion of by-catch to shrimp was 9:1 on the Pacific coast and 3:1 in the Gulf of Mexico. However, discards have a potential economic value so the utilization of these organisms will increase as demand for protein escalates and their retention and processing becomes more economically viable. In particular, the mollusks from the Mexican tropical Pacific are abundant and very diverse with many species of commercial interest. In the coastline of the Gulf of Tehuantepec, mollusks are harvest by hand in coastal lagoons and estuaries by the coastal inhabitants for their own consumption, and for local or regional marketing. Few species are obtained from the incidental catches of shrimp fishery activities. There are no recent evaluations of the specific composition and frequency of mollusks in the incidental catches of the commercial shrimp fishery from the Gulf of Tehuantepec (southern Mexican Pacific) to have more detailed evidence on the current and potential importance of these mollusks in the region. Therefore, the present work provides basic information that may aid to more detailed future studies on this topic.

MATERIALS AND METHODS

The Gulf of Tehuantepec is located in the southern Mexican Pacific and includes the coastline of the states of Chiapas and Oaxaca. This region has estuaries and coastal lagoons with mangroves and long sandy beaches along an approximate extension of 787 km [16] (Figure 1). The continental shelf is wide and homogeneous (50 - 80 km) with an approximate total area of 117,439 km2.

Mollusks were collected during a research campaign for the evaluation of the shrimp resource, on board of the vessel FIPESCO 63 used for the commercial shrimp fishery activities in June 2004. A otter bottom trawl net with mesh size of 50.8mm and total length of 24 m) was used. Trawls were performed in 55 sampling stations at depths between 14 and 65 m from Puerto Chiapas (14°41'17''N - 92°28'74''O) to Salina Cruz, Oaxaca (16°00'53''N - 95°7'74''O). Trawling time was of 35-79 min, with a velocity of 20.3-99.7 m/min along a distance of 1,220-6,580 m per trawl.

Taxonomic identification of mollusks was made with specialized bibliography [17,18]. Taxonomic changes and recent updates according to Skoglund [19,20], and the World Register of Marine Species [21]. The relative abundance of every species was estimated by calculating the ratio between the number of specimens of each species and the total number of specimens of all species collected. In addition, the biological value index (BVI) [22,23], of every species was calculated as an indicator of the importance of the mollusks based on the abundance and frequency of the species in the samples. A reference collection was set up with all the locality information in the Laboratory of Marine Ecosystems and Aquaculture at the Department of Ecology, University of Guadalajara, México. Voucher specimens were also deposited in this laboratory.

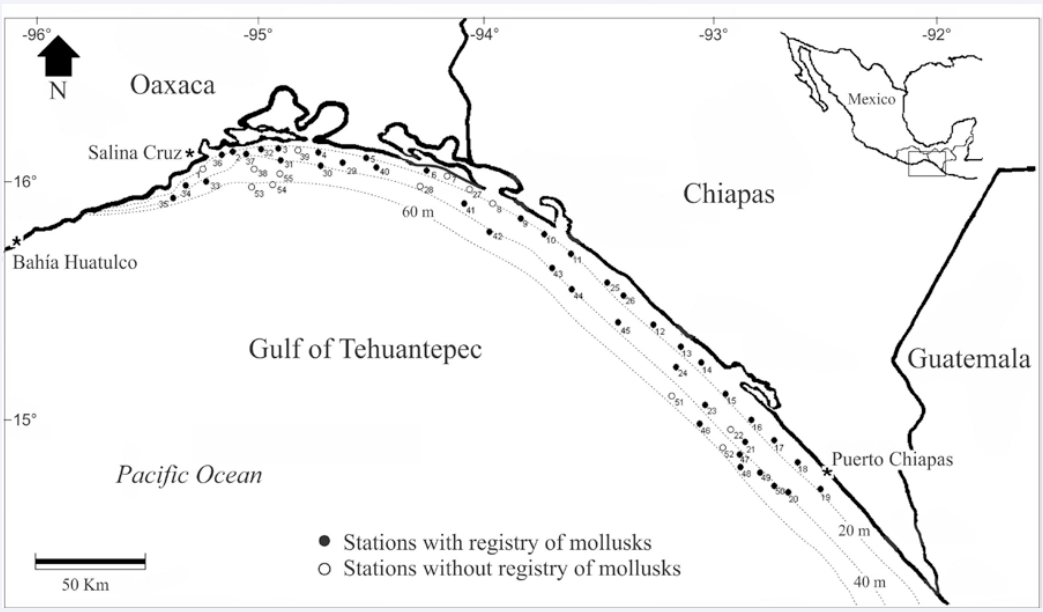

Figure 1 Study area in the Gulf of Tehuantepec, southern Mexican Pacific. The numbers indicate the location of the sampling sites of the continental shelf and the dashed lines the bathymetry of the region.

RESULTS AND DISCUSSION

The mollusks are among the most diverse invertebrates in the coastal tropical environments and the vast majority are found intertidally, in estuaries and coastal lagoons, and in the shallow areas on the continental shelf. Recently, Ríos-Jara et al., [24] made the largest compilation of bivalves and gastropods recorded in the shoreline and continental shelf of the Gulf of Tehuantepec with 213 species (103 bivalves and 111 gastropods). There is certainly a different group of species living in the deeper parts of the shelf but their composition is still not well documented. Indeed, studies on the bathymetric distribution of mollusks in other regions of the Mexican tropical Pacific have shown that the number of species remains relatively high across the shelf as far as the100m depth [24-26].

In the present study, mollusks were recorded in 42 of the 55 sampling stations of the continental shelf between 14 and 47 m with a total of 832 individuals and 59 species. Most specimens (>95%) were collected alive. The bivalves (clams, oysters, cockles, mussels, scallops) were more abundant (525 individuals) than the gastropods (limpets, cup-snails, true snails) (266 individuals) but with lower diversity (bivalves 18 species, gastropods 41) (Table 1). All these species are part of the incidental catches associated to the shrimp fishery in the Mexican Pacific although most of them are not used as food or their shells as art crafts.

Fourteen species had biological value indices higher than 20 points indicating these are quite abundant and frequent in the samples. The scallop *Argopectenirradians* (Lamarck, 1819) (= *A. circularis*) was the most abundant species in all samples with more than 90 % of all mollusks. It was collected in aggregations of > 200 live scallops at depths between 14-46 m. Among the gastropods, 13 species had high BVI values (≥ 33); these represent > 80 % of all gastropods collected: *Harpacrenata* Swainson, 1822, *Granolariasalmo* (Wood, 1828), *Ficusventricosa* (G. B. Sowerby I, 1825), *Crepidulaexcavata* (Broderip, 1834), *Hexaplexbrassica* (Lamarck, 1822), *Malearingens* (Swainson, 1822), *Crucibulumlignarium* (Broderip, 1834), *Fusinusdupetitthouarsi* (Kiener, 1840), *Tonna* sp., *Olivasplendidula* G. B. Sowerby I, 1825, *Melongenapatula*(Broderip & Sower by, 1829), *Conuspatricius* Hinds, 1843, and *Crucibulumpersonatum* Keen, 1958. All specimens, except for the cup-and-saucer snails *C. excavata*, *C.*

Table 1: Mollusks (bivalves and gastropods) captured during shrimp fishery activities in the Gulf of Tehuantepec, Southern Mexican Pacific.

	VBI	TI	RA	ARA	VBI	TI	RA	ARA	VBI
BIVALVES					**GASTRÓPODS**				
1. *Argopectenirradians*	22	491	90,75	90,75	12. *Conuspatricius*	29	16	5,49	71,82
2. *Dosinia ponderosa*	16	13	2,40	93,16	13. *Crucibulumpersonatum*	24	27	9,27	81,09
3. *Crassostreaprismatica*	11	4	0,73	93,90	14. *Olivaincrassata*	18	4	1,37	82,47
4. *Chionepulicaria*	10	8	1,47	95,37	15. *Hexaplexnigritus*	17	4	1,37	83,84
5. *Cyclinellasaccata*	10	2	0,36	95,74	16. *Distorsiodecussata*	13	3	1,03	84,87
6. *Periglyptamulticostata*	10	2	0,36	96,11	17. *Hexaplexradix*	10	3	1,03	85,91
7. *Anadaraobesa*	8	2	0,36	96,48	18. *Olivapolpasta*	9	3	1,03	86,94
8. *Noetiareversa*	8	2	0,36	96,85	19. *Phoscrassus*	7	1	0,34	87,28
9. *Chioneamathusia*	7	1	0,18	97,04	20. *Turritellabanksi*	7	2	0,68	87,97
10. *Harvellaelegans*	7	1	0,184	97,22	21. *Turritellaleucostoma*	7	1	0,34	88,31
11. *Macomalamproleuca*	7	1	0,18	97,41	22. *Cancellariasolida*	6	1	0,34	88,65
12. *Pegophysemaedentuloides*	7	1	0,18	97,59	23. *Crucibulumscutellatum*	6	1	0,34	89,00
13. *Spondyluslimbatus*	3	3	0,55	98,15	24. *Northianorthiae*	6	2	0,68	89,69
14. *Anadarareinhartii*	2	1	0,18	98,33	25. *Vasumcaestus*	6	1	0,34	90,03
15. *Glycymerismaculata*	1	1	0,18	98,52	26. *Bursa corrugata*	5	1	0,34	90,37
16. *Pinctadamazatlanica*	1	3	0,55	99,07	27. *Conus archon*	5	1	0,34	90,72
17. *Trachycardiumpanamense*	1	2	0,36	99,44	28. *Mitraswainsonni*	5	1	0,34	91,06
18. *Trachycardiumprocerum*	1	3	0,55	100	29. *Conusrecurvus*	4	1	0,34	91,40
TOTAL BIVALVES		**541**	**100**		30. *Conasprellatornata*	4	1	0,34	91,75
GASTROPODS					31. *Crucibulumspinosum*	4	1	0,34	92,09
1. *Harpacrenata*	62	34	11,68	11,68	32. *Marsupina nana*	4	1	0,34	92,43
2. *Granolariasalmo*	55	20	6,87	18,55	33. *Stigmaulaxelenae*	4	2	0,687	93,12
3. *Ficusventricosa*	49	19	6,52	25,08	34. *Calyptraeamamillaris*	3	1	0,343	93,47
4. *Crepidulaexcavata*	45	13	4,46	29,55	35. *Cancellariaobesa*	3	1	0,343	93,81
5. *Hexaplex brassica*	44	14	4,81	34,36	36. *Conuspoormani*	3	1	0,34	94,15
6. *Malearingens*	43	10	3,43	37,80	37. *Cymatium weigmanni*	3	8	2,74	96,90
7. *Crucibulumlignarium*	38	18	6,18	43,98	38. *Vokesimurexrecurvirostris*	3	1	0,34	97,25
8. *Fusinusdupetitthouarsi*	33	37	12,71	56,70	39. *Thais kiosquiformis*	3	1	0,34	97,59
9. *Tonna* sp.	33	8	2,74	59,45	40. *Crepidulastriolata*	2	6	2,06	99,65
10. *Olivaspendidula*	31	7	2,40	61,85	41. *Polystirapicta*	1	1	0,34	100
11. *Melongenapatula*	30	13	4,46	66,32	**TOTAL GASTRÓPODS**		**291**	**100**	

Abbreviations: BVI = Biological Value Index; TI = Total number of Individuals collected from all samples; RA = Relative Abundance; ARA = Accumulative Relative Abundance

lignarium, and *C. personatum*, were of considerable size with very attractive shells, which may be used in art crafts and are very appreciated in shell collections.

The scallop *A. irradians*, known in Mexico as catarina clam, is an important fishery resource of high commercial value due to its good taste and beautiful shells frequently used in art crafts. However, the species has reduced populations due to heavy exploitation in Baja California where it is an important fishery [27,28]. Precisely in this region, the species has now a regulated exploitation according to official policies for the protection of endangered species (NOM-004-PESC-1993). Since 1977, there has been an experimental and commercial effort to further developing the mariculture of scallops in Mexico, including *A. irradians*, in the southern Baja California region by the Secretaría de Pesca and the Marine Cultures Company [29].

The thorny oyster *Spondyluslimbatus* G. B. Sowerby II, 1847 (= *S. calcifer*), known in México as almejaburra, is the largest species of *Spondylus* in America with good potential to be used as food. According to Villalejo-Fuerte et al., [28], this oyster has an abductor muscle of almost 50% of the total weight of the soft part of the oyster. However, since the early 1980´s, the banks in shallow waters (< 15 m depth) of this oyster are over-exploited or even depleted by sport and commercial divers [27], and in 2001, *S. limbatus* was included as a protected species in México (NOM-059-ECOL-2001). This is a very attractive species that should be included in recent programs of aquaculture; probably the known technology for seed production and fixation of larvae in oyster farming may be adapted to this particular species.

Other important mollusks that were common in the incidental catch during shrimp fishery in the Gulf of Tehuantepec were the Panama harp *H. crenata*, which was abundant (34 individuals) and frequent in the sampling stations (45.5%) at depths between 28-45 m; the crown conch *Melongenapatula* with an attractive shell that reaches a length of 75-250 mm; and the salmon horse conch *Granolariasalmo* with a shell size 80-150 mm. These snails together with several species of the family Muricidae [e.g. *Hexaplexbrassica*, *Hexaplexnigritus* (Philippi, 1845), *Hexaplexradix* (Gmelin, 1791), *Vokesimurexrecurvirostris* (Broderip, 1833)] are frequently used when collected alive. These species are selected and stored frozen in bags in the lower deck warehouse of the vessel for a later sale in Puerto Chiapas or Salina Cruz, when the refrigerator capacity permits their storage depending on the amount of shrimp caught.

Most of the large to medium sized species of several abundant gastropods belonging to families Conidae, Fasciolaridae, Ficidae, Olividae, Naticidae, Calyptraeidae, and Tonnidae should also be harvested during the selection of shrimps on the deck of the vessel to be used as food and their shells in crafts or as pieces of ornamental value. This may be worth doing instead of discarding them to the sea already dead or badly damaged. In this group are the snails *Ficusventricosa*, *Malearingens*, *Fusinusdupetitthouarsi*,*Tonna* sp., *Olivasplendidula*, *Conuspatricius*, *Olivaincrassata* (Lightfoot, 1786), *Conusrecurvus* Broderip, 1833, *Conasprellatornata* (G. B. Sowerby I, 1833), *Stigmaulaxelenae* (Récluz, 1844), *Calyptraeamamillaris, Conuspoormani*. *Calyptraeamamillaris* Broderip, 1834, and *Conuspoormani* Berry, 1968.

Regarding the composition of the incidental catches associated with the shrimp fishery, recent evaluations in the Mexican Pacific indicate that mollusks are the third group in importance after the fish and crustaceans [30]. In the Gulf of California estimations of 150,000 t/year of by-catches include 3-8% of mollusks (31 species) [31]; and in the Gulf of Tehuantepec the by-catch reported is more than 60% of the total catches [32]. Kelleher [33], cites estimates of by-catch in the form of discards in the Mexican shrimp trawl fishery of 119,000 tons, based on ratios of by-catch to target catch of 3:1 in the Gulf of California fishery, and 2:1 elsewhere. From the 1960s to the 1980s, the size of net mesh was reduced from 64 to 38 mm, and the size of the shrimp captured was reduced on average by 21 % [34]. For the 2000–2003 period, the estimate of 10 lb (by weight) of by-catch for every pound of shrimp caught was deemed applicable to the Mexican shrimp industry [35]. There are no estimations of marketed non-shrimp by-catch, so all but the shrimp catch is considered to be discarded. Mexico's shrimp production averaged 57,000 tons from 2000 to 2003, so the average annual by-catch for Mexico is estimated at 570,000 tons. That represents 38 % of average total marine catch (including discards) of 1,500,000 tons [3].

Since 2012, Mexico has actively participated in the FAO/GEF/UNDP project "Reduction of the Environmental Impact from Tropical Shrimp Trawling through the Introduction of By-catch Technologies and Change of Management". This participation has included gear technology work, training of observers and transfer of technology to other Latin American countries [36]. Most technologies to reduce by-catch have involved placing a TEDs (Trawl Exclusion Device) or BRDs (By-catch Exclusion Device) in the cod end of the trawl. The modified network has proved to reduce incidental capture 21% on average compared to conventional networks [6]. For example, Sarmiento-Nafate et al., [37] compared by-catch using the conventional trawling net and a newly designed short funnel net, during nine cruises carried out by the commercial fleet operating in the Gulf of Tehuantepec, Mexico. A total of 480 trawls were done (mean duration: 85 min). The experimental trawls using the modified net produced a 21.13-28.86 % by-catch reduction, a 3 % increase of shrimp catch, and a significant reduction on net recovery time. However, all these efforts have not achieved complete success because there is no reliable information on which species are frequently part of the by-catch, what are their real volumes, how the species composition changes during the year and along in different regions. Without this information, it is difficult to establish successful strategies to promote the use of by-catches and to reduce the discards.

However, according to Eayrs [38], the issue of by-catch in tropical shrimp-trawl fisheries around the world, is not going away and fishermen will always be under pressure to reduce catches of non-target animals and non-living material. However, in many countries fishermen have already come a long way and by-catch has been dramatically reduced. TEDs are now used in most tropical shrimp-trawl. While the overall performance of these devices is not spectacular, at least some by-catch is being excluded. The future of by-catch reduction probably lies in better management of fishing activity and the development of effective BRDs. The management of fishing activity can be improved by introducing area or seasonal closures, particularly in locations

that are nursery grounds for juvenile fish and other animals. In many countries this is already a commonly used option because it is immediately effective.

Finally, there have been many attempts to use the by-catches, such as the designing shrimp boats with an onboard plant to produce shellfish derived flour and fishmeal. There are examples of the use of non-commercial shrimp by-catch as raw material for the elaboration of traditional or non-traditional fish products including hamburgers, breaded fillet, pasta, and salami with an excellent presentation and good nutritional value [39,11,12,40]. Evaluations of the chemical composition and energy content of the shrimp by-catch from Veracruz (Gulf of Mexico) suggest used that at least 22 species of fish and one mollusk (squid) have good potential for human and livestock consumption [41]. However, nutritional composition (e.g. protein and lipid content) should vary depending on species, environment, sex, and season [42]. Again, it is desirable to perform more research to recognize alternatives to the use of shellfish associated with shrimp fisheries in the southern Mexican Pacific. Recent evidence from the countries of Central America and the Caribbean suggest that the amount of incidental catch that is now utilized in the region [1]. The trend for greater and more complete utilization of by-catch has been noted over the years and as Andrew and Pepperell [43,44], state, "It seems likely that the utilization of by-catch will increase as demand for protein escalates and the retention and processing of by-catch becomes more economically viable".

CONCLUSION

There is a great diversity of mollusks associated to the shrimp in the Gulf of Tehuantepec (southern Mexican Pacific). Some of these species are being exploited but most of them are discarded even though they have potential use as human food or livestock consumption, and their shells in crafts or as pieces of ornamental value. The non-commercial shrimp by-catch, which today has little or no commercial value in the Gulf of Tehuantepec, may be worth used and become the main raw material for the elaboration of products based on shellfish derived flour and fishmeal. Other studies suggest they are an excellent raw material for the production of a variety of products for human or animal consumption and can supply a good amount of proteins.

Although significant efforts have been made to reduce by-catches and discards associated to shrimp fishery in Mexico, there is still a lack of information about the composition and abundance of mollusks associated with shrimp fishery, and on their seasonal and regional changes along the Mexican Pacific.

ACKNOWLEDGEMENTS

We thank Christian Tovilla (El Colegio de la Frontera Sur, UnidadTapachula), for his kind invitation to perform this research work in his laboratory and to Saul Sarmiento Nafate (Centro Regional de Investigaciones de Salina Cruz) for providing the mollusks collected on board the vessel FIPESCO 63. We are also grateful to Ceciel Navarro Caravantes for his help during preliminary taxonomic identification of mollusks. The Universidad de Guadalajara provided financial support for this research.

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Cite this article

Ríos-Jara E, Galván-Villa CM, Ayón-Parente M, Rodríguez-Zaragoza FA, Díaz-Pérez L (2016) Incidental Catch of Mollusks Associated with Shrimp Fishery in the Gulf of Tehuantepec, Southern Mexican Pacific. Ann Aquac Res 3(1): 1016.