6-1-2018

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Pakistan J. Zool., vol. 50(3), pp 941-949, 2018. DOI: http://dx.doi.org/10.17582/journal.pjz/2018.50.3.941.949

Feeding Patterns of Two Commercially Important Fish Species *Scomberoides commersonnianus* and *S. tol* in the Northern Arabian Sea Coast of Pakistan

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Article Information
Received 09 March 2017
Revised 01 July 2017
Accepted 21 July 2017
Available online 17 April 2018

Authors' Contribution
SKP and NQ designed the experiments and assisted in data collection. RR, SKP and NQ analysis the data and wrote the manuscript.

Key words
Fisheries, Trophodynamics, Fish, Ecology, Food web.

ABSTRACT

Port landing of *Scomberoides commersonnianus* and *S. tol* were obtained between July 2013 and June 2015 for stomach content analysis. Analysis of prey composition was done using permutational analysis of variance (permanova), with species, life stage (juvenile and adults), gender, and weather (rainy and dry season) as factors. Patterns of empty stomachs were investigated to estimate feeding intensity. Feeding intensity was estimated with logistic regression, using the same independent variables as above. Prey importance was also investigated. Prey importance was assessed using a Wilcox Rank Correlation analysis on the Index of Relative Importance (IRI) by species and life-stage. Permanova analysis showed that fish was the most important dietary item for juveniles and adults. Adults secondarily preferred crustaceans. Fish was predominant for S. *commersonnianus* and crustaceans, especially of the genus *Acetes* sp., was equally important for *S. tol*. *Acetes* sp. was more important during the dry season for both, *S. commersonnianus* and *S. tol*. Adults of both species showed a higher feeding activity. The IRI showed fish, followed by crustaceans, to be the most important food item for *S. commersonnianus* and *S. tol*. This study is to offer baseline data toward implementing a fishery in Pakistan for current and future generations.

INTRODUCTION

Knowledge of interactions between predator and prey has been long recognized as essential in shaping aquatic communities (Rosenzweig and MacArthur, 1963; Paine, 1966, 1969; May, 1973) and necessary for improving reliability of fisheries management, especially management taking consideration ecosystems (Larkin, 1996). The concept of ecosystem-based fisheries management has demonstrated superior to traditional and often simplistic strategies for conserving marine resources, based on single species or a small group of target fish (Fulton *et al*., 2014). The implementation of ecosystem-based fisheries management, however, requires sound knowledge of the indirect effects of fishing, including changes in food webs and trophic interactions. Interactions between predator and prey may raise two concerns for fisheries management. The first one are direct effects leading to variation in food resources and the second are indirect effects causing changes in ecosystem functioning.

Direct changes in marine food availability mediated by fishing may come from harvests or discards. Fish harvest has been shown to affect food availability and body condition of predatory fish (Hiddink *et al*., 2016). Similarly, discards have been shown to be an important resource for birds, mammals, and fish (Heath *et al*., 2013; Oro *et al*., 2013). Indirect changes from fishing may affect the ecosystem by removing individual fish of different ecological roles, changing ecosystem processes (Hughes, 1994; Mirza, 2003). By changing the size structure of target fish populations, fishing has been shown to affect sediment removal by parrotfish (Bellwood *et al*., 2102) and the spatial range of grazing by herbivorous fish (Nash *et al*., 2013). Larger fish provide their functional role over larger areas, indicating that the effects of fishing have much subtler and significant ramifications than traditionally thought.

The coast of Pakistan comprises of highly diverse habitats, supporting a productive commercial and subsistence fishery. One of the most important fish in terms of landings and value are species of the genus *Scomberoides*, which mainly comprise of *S. commersonnianus*, *S. tala*,

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0030-9923/2018/0003-0941 $ 9.00/0

S. tol and *S. lysan* in Pakistan (Qamar *et al*., 2016). With rapid population growth, including development of tourism, broadening of the country's industry base, and expansion of the residential sector, the coast of Pakistan is changing. With the increase of population comes the associated increase in fisheries exploitation to meet the demands for food. Meaningful ecological baselines to support fisheries management are rare because the fisheries in Pakistan remain understudied. A few studies describing the occurrence of species (Psomadakis *et al*., 2015; Qamar *et al*., 2016) and the fisheries in Pakistan (Panhwar *et al*., 2014; Qamar, 2015; Qamar *et al*., 2016) are not enough to establish effective regulations to manage the fishery in the country.

This study is a start to bridge the gap between data and information to allow resource managers to prioritize conservation and regulation practices in Pakistan. Limited dietary data is available for marine fish species in Pakistan, which hinders the development of sound management practices in the country and contribute to the current overfishing and depletion of many of its stocks, with unknown indirect effects to its marine ecosystem. The main objective of this study is to provide necessary baseline data to start working toward implementing a fishery in Pakistan that will be sustained into the future.

Table I.- Quantity, lengths (cm) and weights (g) of *Scomberoides commersoniannus* and *S. tol* sampled from Karachi Harbor, Pakistan, landings for stomach content analysis.

Month	*S. commersoniannus*			*S. tol*		
	N	Min length	Max length	N	Min weight	Max weight
Jan	13	18.8	40.4	18	18.9	37.4
Feb	37	16.4	30	34	21.4	40.2
Mar	28	18	42.7	59	20	48.7
Apr	36	18.7	88.4	45	21	51.5
May	43	18.5	45.4	44	21.2	48.6
Jun	44	18	64.3	17	20.2	68
Jul	32	17.7	59.5	34	23.9	47.3
Aug	49	17.7	39	35	20	47
Sep	47	18.1	43	36	22.5	52
Oct	33	17.9	43	49	19.6	45.5
Nov	14	17.5	35.3	14	20.5	43.5
Dec	13	17	41.8	16	20.2	57.7
Total		**389**			**401**	

MATERIALS AND METHODS

Study area and sampling

Seven hundred and ninety specimens of *S. commersonniamus* and *S. tol* were obtained from port landings at the Karachi Harbor between July 2013 and June 2014. Fish sampled were caught by purse-seines, gillnets, and trawls at depths ranging from 5 to 50 m (Fig. 1). Approximately 15 specimens of each species were obtained monthly between November and January, and over 25 (except June for *S. tol*) for the remainder of the sampling period. Specimens of *S. tol* were slightly more abundant from port samplings (Table I).

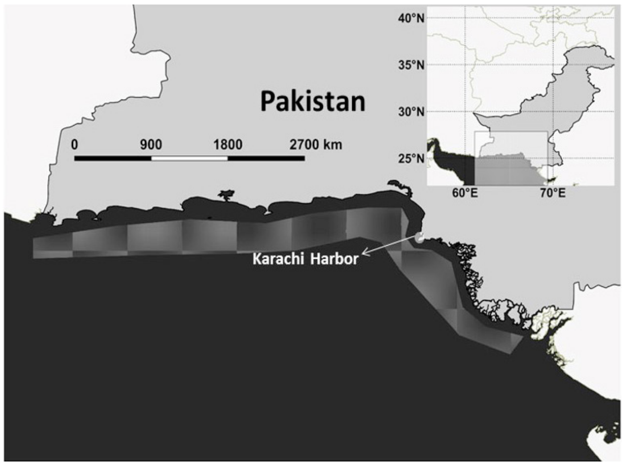

Fig. 1. Study area of feeding patterns of *Scomberoides commersiannus* and *S. tol*. Shaded area along coast indicates location of commercial fishing grounds.

Fish processing and statistical analyses

Fish obtained were stored in ice and taken to laboratory within one hour for processing. Each fish was sexed, measured to the nearest millimeter, and weighed to the nearest gram. Stomach content for each fish was removed and weighed to the nearest gram. Stomachs were emptied and re-weighed to obtain weight of its contents. Stomach contents were placed in a petri dish for examination under a microscope. Number and weight of each prey item were recorded for each stomach. Identification of prey items was done to the lowest possible taxa.

Analysis of prey composition was done to assess patterns of feeding according to species, life stage, gender, and weather. Weather was taken as either rainy or dry, according to whether the sampling occurred during monsoon months (November and December; May and June) or outside such period, respectively. Life stage was either juvenile or adult. Life stage was obtained by examining modes of fish length plots.

Because data from each specimen yielded multiple prey taxa, we opted to analyze patterns of prey composition using multivariate statistical methods. Prey composition was examined using permutational analysis of variance (permanova) on factors denoting species, life stage, gender, and weather, all with two levels as indicated above. Fish with empty stomachs were not included in analysis for prey composition. Permanova was chosen due to relaxation of data homoschedasticity as an underlying assumption of analysis. The Bray-Curtis distance matrix was used as the basis for estimating effect size and significance of factors.

Patterns of fish feeding activity were estimated using empty stomachs as a surrogate for no feeding. Activity was examined using binomial logistic regression. Fish were coded as either 0 (empty stomach) or 1 (content present). Codes were taken as the response variable. The independent variables were as above for the permanova analysis. The logit link function for the regression was used. Data were split to test for model fitting. The training set comprised of 85 percent of the data and the remainder of data was assigned to the testing set. Deviance decline following the regression analysis was used to assess the effect of the independent variables in estimating the response. To analyze decline in deviance, a chi-square analysis of variance was used. In addition to model fitting, model predictive ability was also assessed. Predictive ability was tested with the testing dataset using a decision boundary probability of 0.5. The area under the curve of a Receiving Operating Characteristic plot was used as an additional test for model predictability.

Prey importance as a function of species and life stage was also analyzed. Prey importance was estimated using the well-established Index of Relative Importance (Hyslop, 1980), where the percent occurrence of a prey taxa is multiplied by the sum of the percent of prey weight and percent of prey number. The IRI for species, irrespective of life-stage, and the IRI for life-stage, irrespective of species, were calculated. A Wilcox Rank Correlation analysis was used to estimate prey importance by species and life-stage.

RESULTS

Length plots indicated that adult fish for both species were larger than approximately 30 cm (Fig. 2). The average weight for sampled fish was 257.6 g ± 8.52 Standard Error of the Mean (SEM) for *S. commersonnianus* and 225.1 g ± 16.72 SEM for *S. tol*.

Permanova results showed that consumed prey biomass was a function of life stage, species, and weather (Table II). For life stage, the importance of fish in the diets of both, juveniles and adults was highest. For adults, crustaceans of the genus *Acetes* spp. also played a major role in diets (Fig. 3). Fish was the most important prey for *S. commersonnianus*, whereas a combination of fish and crustaceans were more important for *S. tol*, especially crustaceans of the genus *Acetes* spp. (Fig. 4). On average, *S. commersonnianus* consumed more prey by weight than *S. tol* (2.49±0.94 SEM and 2.58±0.31 SEM, respectively). Fish was the predominant diet during both, the low and high rain season. The commonly found food item *Acetes* spp. was more important during the low rain season (Fig. 5).

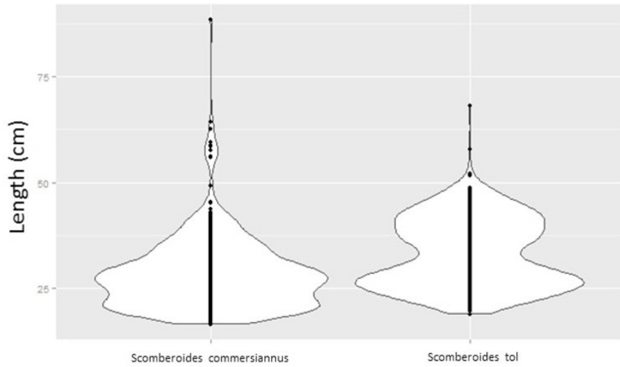

Fig. 2. Violin plot of length distribution of *Scomberoides commersoniannus* and *S. tol* sampled along the Pakistani coast.

Table II.- Permanova output results of prey biomass on fish species, fish gender, life stage (juvenile and adult), and weather (rainy or dry season) for *S. commersoniannus* and *S. tol* sampled from landings in Pakistan between July 2013 and June 2014.

Source	df	SS	MS	Pseudo-F	p-value
Fish species (Fi)	1	26361	26361	6.82	<0.001
Life stage (St)	1	28115	28115	7.27	<0.001
Fish gender (Ge)	1	3742.4	3742.4	0.97	0.42
Rainy season (Ra)	1	17972	17972	4.65	<0.001
Fi x St	1	12298	12298	3.18	0.01
Fi x Ge	1	4007.5	4007.5	1.04	0.41
Fi x Ra	1	4464.5	4464.5	1.16	0.31
St x Ra	1	8379.9	8379.9	2.17	0.03
Se x Ra	1	3501.8	3501.8	0.91	0.49
Res	575	$2.2223x10^6$	3864.8		
Total	**584**	**$2.3574x10^6$**			

df, degrees of freedom; SS, sums of squares of residuals; MS, mean squares.

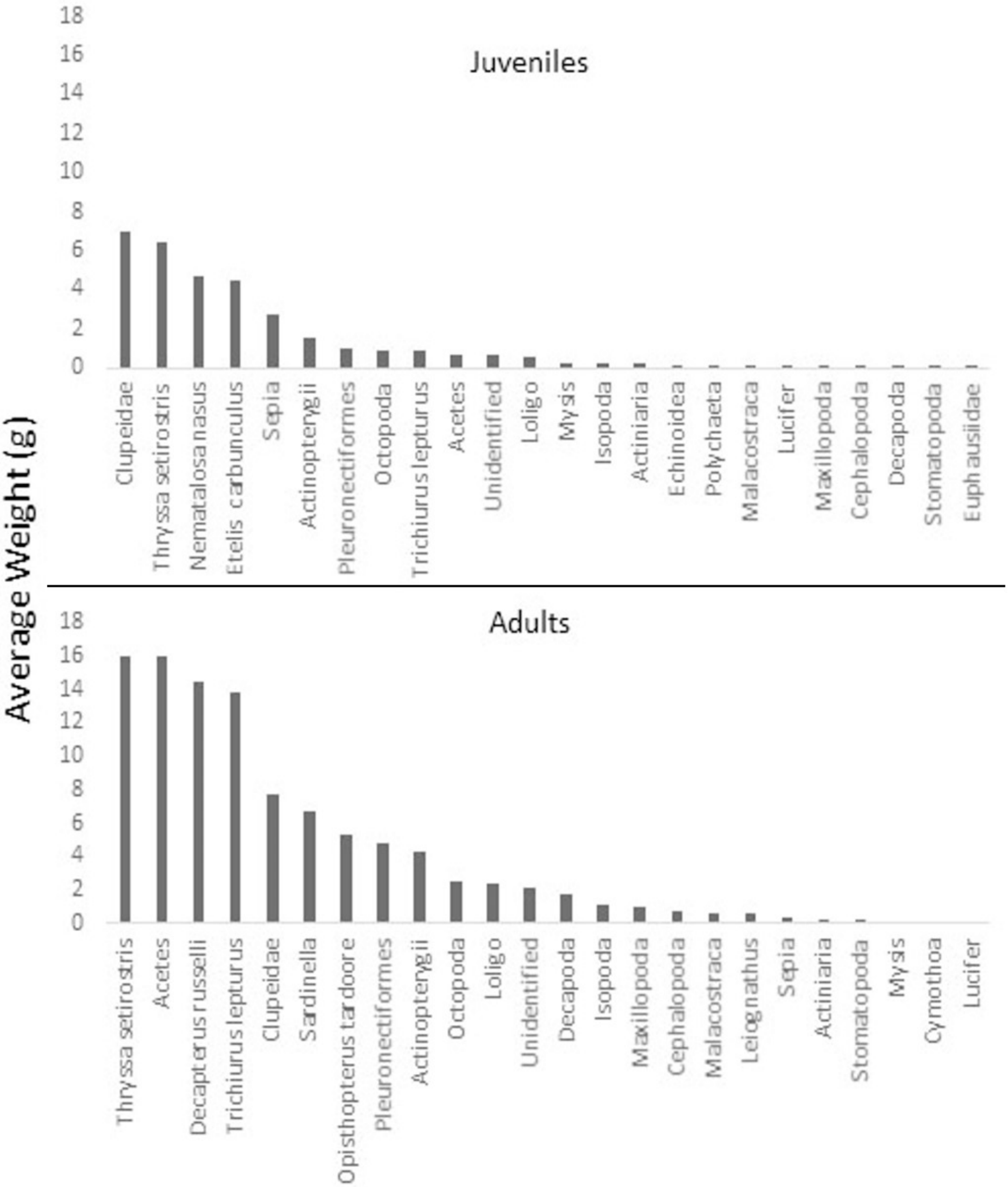

Fig. 3. Average weight of prey items in stomach of juvenile and adult *Scomberoides commersoniannus* and *S. tol* sampled from landings in Pakistan between July 2013 and June 2014; data pooled for species.

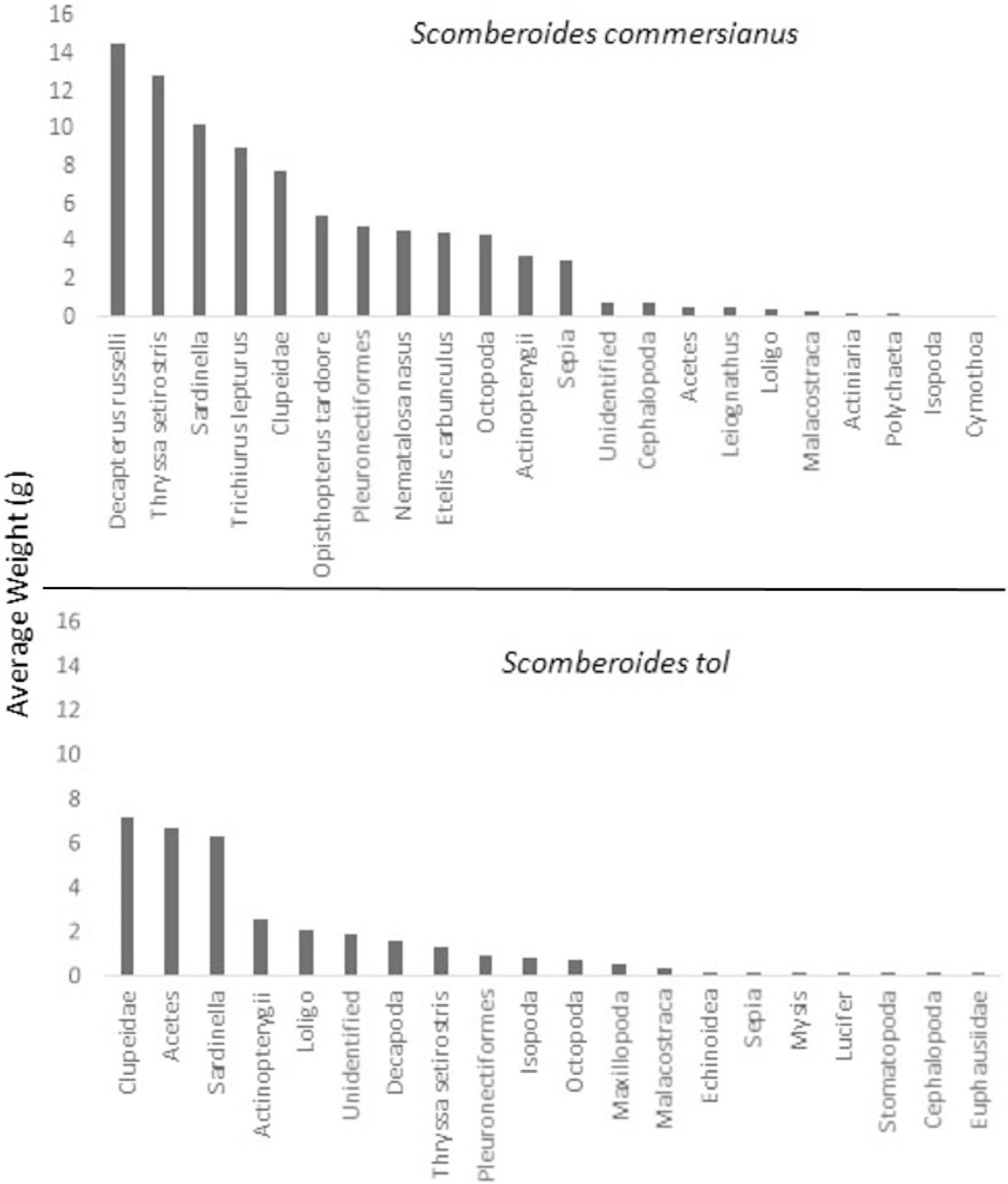

Fig. 4. Average weight of prey items in stomach of *Scomberoides commersoniannus* and *S. tol* sampled from landings in Pakistan between July 2013 and June 2014.

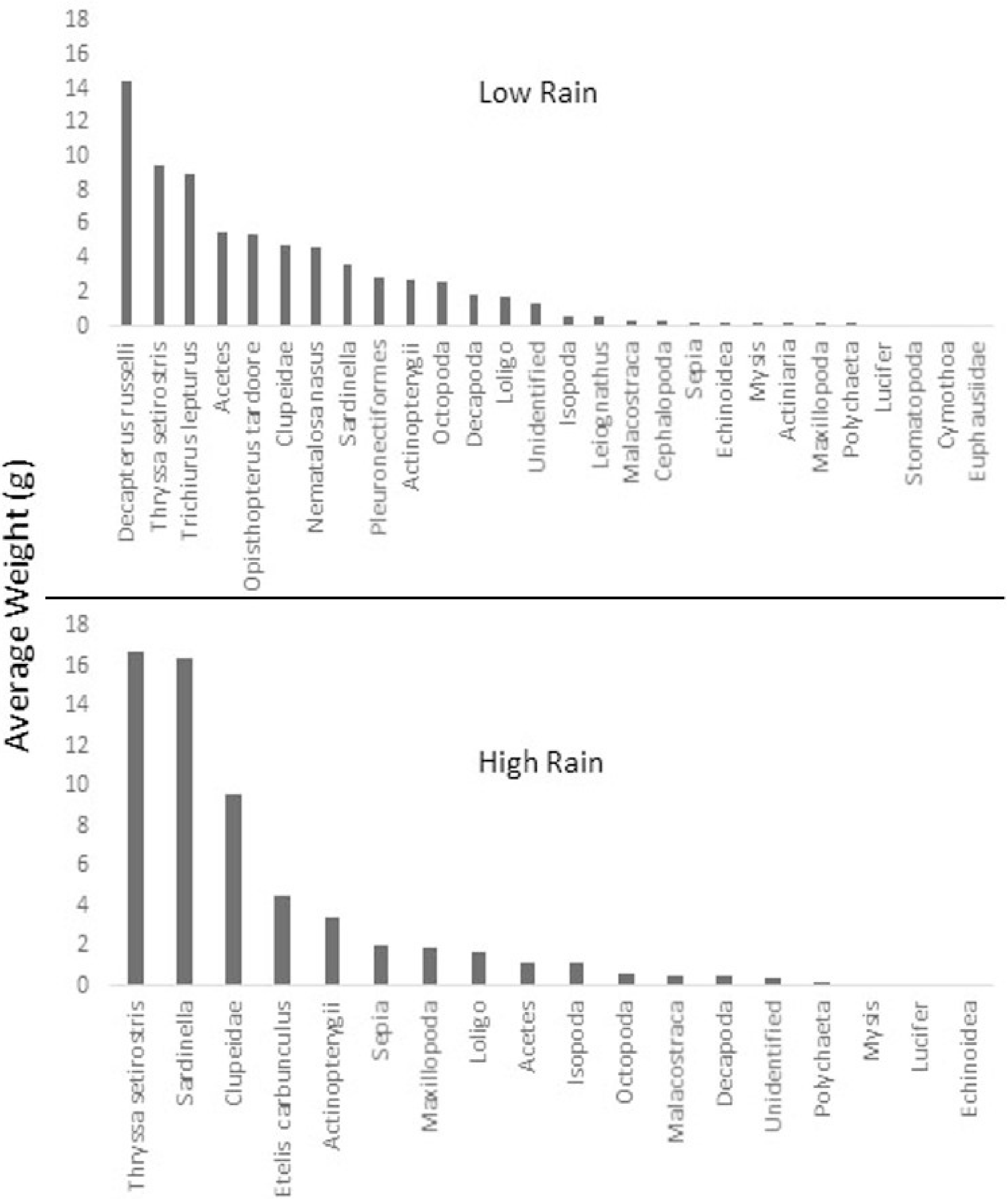

Fig. 5. Average weight of prey items in stomach of *Scomberoides commersoniannus* and *S. tol* by season (rainy and dry) sampled from landings in Pakistan between July 2013 and June 2014; data pooled for species.

Table III.- Binomial logistic regression results of stomach emptiness on species, gender, life stage, and weather for *S. commersoniannus* and *S. tol* sampled from landings in Pakistan between July 2013 and June 2014.

Source	df	Estimates	S.E.	Z-score	p-value
Intercept	1	1.65	0.32	5.1	< 0.01
Species	2	1.13	0.23	4.8	< 0.01
Rainy season	2	0.16	0.23	0.7	0.49
Age class	2	-0.54	0.23	-2.3	0.02
Gender	2	-0.23	0.23	-1.0	0.32

Rainy season, Monsoon and non-Monsoon; age class, juvenile and adult; total degrees of freedom (df), 790.

Fish species and life-stage were the only factors influencing feeding activity, as measured by stomach emptiness. Logistic regression results showed that juveniles irrespective of species and *S. tol* irrespective of life-stage were more likely to have empty stomachs. Weather and gender did not influence patterns of stomach emptiness. Regression model from the testing data showed an accuracy of 82 percent correct estimates of emptiness (Table III). The area under the curve for the ROC plot was 0.69 (Fig. 6).

Index of Relative Importance showed no patterns for species or life-stage. Pooling all data, unidentified fish showed the highest rank, followed by crustaceans of the genus *Acetes* spp., unidentified prey, and isopods. The least important prey species constituted of mostly demersal organisms (Tables IV and V).

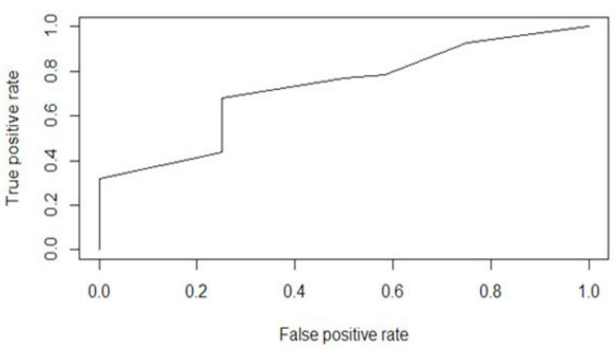

Fig. 6. Receiver operating characteristic plot indicating performance of binomial logistic regression of stomach emptiness on species, gender, life stage and weather for *Scomberoides commersonianus* and *S. tol* sampled from landings in Pakistan between July 2013 and June 2014.

Table IV.- Prey index of relative importance (IRI) for *S. commersoniannus* and *S. tol* sampled from landings in Pakistan between July 2013 and June 2014.

Taxa	IRI	Taxa	IRI
Actinopterygii	1397.29	*Stomatopoda*	0.25
Acetes spp.	867.55	*Octopoda*	0.12
Unidentified prey	124.32	*Nematalosa_nasus*	0.11
Isopoda	112.20	*Decapterus russelli*	0.08
Clupeidae	74.65	*Pleuronectiformes*	0.07
Malacostraca	35.67	*Cephalopoda*	0.03
Decapoda	29.41	*Opisthopterus tardoore*	0.03
Thryssa setirostris	27.29	*Actiniaria*	0.03
Mysis spp.	18.65	*Echinoidea*	0.03
Maxillopoda	10.45	*Etelis carbunculus*	0.03
Trichiurus lepturus	4.66	*Euphausiidae*	0.02
Loligo spp.	4.31	*Polychaeta*	0.01
Sardinella spp.	2.81	*Leiognathus*	0.01
Lucifer spp.	2.18	*Cymothoa* spp.	0.00
Sepia spp.	0.31		

Table V.- Prey composition and biomass for *S. commersoniannus* and *S. tol* sampled from landings in Pakistan between July 2013 and June 2014.

S. commersoniannus		*S. tol*	
Prey taxa	**Prey biomass**	**Prey taxa**	**Prey biomass**
Acetes spp.	17.13	*Acetes* spp.	560.36
Actiniaria	0.52	*Actinopterygii*	341.69
Actinopterygii	411.93	*Cephalopoda*	0.14
Cephalopoda	0.73	*Clupeidae*	128.68
Clupeidae	178.79	*Decapoda*	42.61
Cymothoa	0.05	*Echinoidea*	0.5
Decapterus russelli	14.5	*Euphausiidae*	0.01
Etelis carbunculus	4.48	*Isopoda*	29.85
Isopoda	0.2	*Loligo* spp.	27.29
Leiognathus spp.	0.55	*Lucifer* spp.	0.83
Loligo spp.	1.82	*Malacostraca*	16.23
Malacostraca	0.72	*Maxillopoda*	13.16
Nematalosa nasus	9.28	*Mysis* spp.	3.47
Octopoda	4.42	*Octopoda*	1.49
Opisthopterus tardoore	5.36	*Pleuronectiformes*	0.93
Pleuronectiformes	4.81	*Sardinella* spp.	43.85
Polychaeta	0.29	*Sepia* spp.	0.66
Sardinella spp.	10.29	*Stomatopoda*	0.45
Sepia spp.	5.94	*Thryssa setirostris*	2.6
Thryssa setirostris	231.41	Unidentified	85.56
Trichiurus lepturus	71.93		
Unidentified	64.61		

DISCUSSION

This study demonstrates that *S. commersonnianus* and *S. tol* are carnivore piscivores, feeding opportunistically on crustaceans and mollusks. Both species showed differences in the quantity of food consumed. *S. tol* on average showed a lower prey quantity than did *S. commersonnianus*, despite their similarity in weight. *S. tol* in Pakistani waters are active at different times during the day (Qamar, 2015). *S. commersonnianus* and *S. tol* both occur in open waters, with the latter species being nocturnal and the former active during daylight. The occurrence of the mostly nocturnal crustacean *Acetes* spp. as a major prey, together with the high occurrence of pelagic fish in stomachs, confirms a nocturnal behavior for *S. tol*. Additionally, the finer gill rakers in *S. tol* explains why this species is more successful in feeding on the small *Acetes* crustacean (Magnuson and Hettz, 1971). For *S. commersonnianus*, conversely, the higher proportion of pelagic fish, implies in diurnal feeding.

Also as expected, juveniles had a lower feeding rate than did adults, as indicated by the higher incidence of empty stomachs in the former. Adult fish also showed a more selective diet toward forage fish and crustaceans. Juvenile fish probably were opportunist, swimming near adult fish schools to feed on forage fish escapees or pieces of prey left behind by adult fish, as has been observed for other fish species (Gerking, 1994). The large occurrence of empty stomachs could also be due to the size of fish, compared to that of the prey. As juveniles, their higher metabolism might have explained the higher incidence of empty stomachs (Longhurst, 1957).

Studies on fish diet have demonstrated the importance of temperature and other environmental factors in feeding intensity and patterns (Gerking, 1994; Alabaster and Lloyd, 2013). This study also demonstrated that the physical environment plays a significant role in determining feeding patterns in Pakistani marine systems. Higher feeding intensity was suggested during rainy seasons, as caused by the Monsoon phenomenon. High rains may affect feeding success through indirect effects of higher river nutrient inputs, increasing prey concentrations at feeding grounds. The composition of food in stomachs also showed a pattern according to season. Fish as prey was more common during the rainy season, whereas during the dry season, a more even pattern, including crustaceans and mollusks, was observed. This latter pattern could have been influenced by the higher abundance of *Acetes* shrimp in Pakistani coastal waters during dry months (Qamar *et al*., 2015).

CONCLUSION

This study showed variation in diet between two closely related species. This study also showed variation within each species and according to environmental factors. Changes in feeding according to life stage, season, and between piscivore species indicates that trophic relations among fish are subtler and possibly more complex than initially thought or reflected in current management practices and regulations. Fisheries management in Pakistan is rudimentary, without effective management plans for even the most important commercial species. Gear restrictions are the only control for excess harvest, instead of the more needed quotas, seasonal/area closures, or size limits. To implement effective regulations toward the maintenance and preservation of commercial stocks, studies such as this need to take the forefront. Investigating trophic interactions will shed light into the many relations between forage fish and their predators, both of which are commercially important in Pakistan. This work is a start toward the development of a more effective fisheries management plan, a plan that follows a more holistic, ecosystem-based approach. With this and forthcoming related studies, a clearer picture can be constructed of the various energy links in marine systems, which in turn can produce a brighter picture for the sustainability of Pakistani's marine resources.

Statement of conflict of interest

Authors have declared no conflict of interest.

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