Pakistan J. Zool., vol. 50(1), pp 135-141, 2018. DOI: http://dx.doi.org/10.17582/journal.pjz/2018.50.1.135.141

Fishery Appraisal of *Portunus* spp. (Family Portunidae) using Different Surplus Production Models from Pakistani Waters, Northern Arabian Sea

Muhsan Ali Kalhoro[1,2], Danling Tang[1,*], Ye Hai Jun[1], Morozov Evgeny[1], Sufen Wang[1] and Muhammad Aslam Buzdar[2]

[1]*Research Center for Remote Sensing of Marine Ecology and Environment, State Key Laboratory of Tropical Oceanography, South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou, 510075, China*

[2]*Faculty of Marine Sciences, Lasbela University of Agriculture, Water and Marine Sciences, Uthal, Balochistan, Pakistan*

Article Information
Received 16 November 2016
Revised 03 March 2017
Accepted 24 April 2017
Available online 02 January 2018

Authors' Contributions
DT supervised and designed the study. MAK executed the experimental work, analysed the data and wrote the article. YHJ, ME, SW and MAB helped in writing of the article.

Key words
Fisheries statistics of Pakistan, Crab fishery, *Portunus* spp., Maximum sustainable yield, overexploitation, CEDA, ASPIC.

ABSTRACT

Annual catch and effort data were used to estimate the maximum sustainable yield (MSY) of *Portunus* spp. to evaluate the population state of crab fishery from Pakistani waters. The catch and effort data of crab fishery from 1999-2009 were obtained from and handbook of Fisheries Statistics of Pakistan. Two computer software programs CEDA and ASPIC were used which were based on surplus production models. From CEDA Fox, Schaeder and Pella-Tomlinson were used with initial proportion (IP) 0.9 were used because the starting catch was 90% of the maximum catch the MSY estimated value from Fox with three error assumptions (normal, lognormal and gamma) were 3378 (R^2=0.590), 3360 (R^2=0.582), 3369 (R^2=0.586), respectively, whereas the obtained values from Schaefer and Pella-Tomlinson with three error assumptions were 2878 (R^2=0.587), 3035 (R^2=0.578) and gamma were minimization failure (MF) in both models. The MSY estimated value from ASPIC from Fox and logistic model were 3652 (R^2=0.8) and from logistic model were 2962 (R^2=0.799), respectively. The present estimated values from surplus production models is lower than annual catch it shows that the stock of crab fishery from Pakistani waters is in overexploitation state, we may suggest to reduce the fishing efforts to sustain the crab stock from Pakistani waters for future generation.

INTRODUCTION

Management of world's marine fin and shellfish stock is sustained by scientific recommendation based on stock assessment using different research tools (Mace *et al*., 2001). Marine Fisheries sector of Pakistan has diversity of marine species from which marine crab species are also one of the valuable sources of economic value because most of the catch export to different countries of the world from which mainly export to China, Middle East and also South East Asian Countries. Pakistani waters are located at Northern part of the Arabian Sea coastline about 1120 km divided into Sindh and Balochistan coastline from Northwest Iranian border and Southwest Indian border from which Sindh coast have 348 km and Balochistan coast comprises about 772 km and about 290,000 km^2 (Fig. 1) from which Pakistan can explore and exploit their marine resources. About 60% of total fish landing is primarily from marine sector and according to FAO (2009), there are about 250 demersal fish species, 20 and 50 are large and small pelagic fish species, respectively, 17 are different crab species and 15 are most commercially important shrimp species from Pakistani waters. FAO (2009) report shows that the major marine resources of the Pakistan are decreasing since 1999.

About 4500 crab species were found from the world from which more than 200 species have been reported from Pakistani water (Kazmi, 2003) out of 200 species five species are most commercial and edible fish species from Pakistani waters which are *Portunus pelagicus* (Linnaeus, 1785), *Portunus sanguinolentus* (Herbst, 1783) *Scylla tranquebarica* (Fabricius, 1798), *S. olivacea* (herbst, 1796) and *Charybdis feriatus* (Linnaeus, 1785). Portunidae crab family species are distributed throughout the Indo-west Pacific and plays important fishery role in different parts of the regions (Stephenson, 1962; Potter *et al*., 1983; Kailola *et al*., 1993; Afzaal *et al*., 2016). Pakistani crab fishery is mainly sustained by two species first the three spotted swimming crab, *Portunus sanguinolentus* (Herbst, 1783)

* Corresponding author: lingzistdl@126.com
0030-9923/2018/0001-0135 $ 9.00/0

and *Portunus pelagicus* (Linnaeus, 1758) from which *P. sanguinolentus* is dominant fish species from Pakistani waters and mostly caught from bottom gillnet or shrimp trawling fresh and frozen crabs were exported to different countries especially China and Middle East. Previous work is available on the biology of the *Portunus* spp. from Pakistani waters (Kazmi, 2003; Takween and Qureshi, 2001, 2005; Rasheed and Mustaquim, 2010; Afzaal *et al*., 2016). *Portunus* spp. were distributed in Indoa-Pacific region (Apel and Spiridonov, 1998) and mostly found at estuary areas where muddy or sandy bottom at about 50-65 m depth (Sumpton *et al*., 1989; Edgar, 1990). Present catch and effort data from 1999-2009 (Table I) shows that most of the catch were from Sindh coastline it maybe because of favorable habitat for the crab fishery, Sindh coastline have freshwater inflow from Indus River which may create best nursery and growing habitat for marine organisms (Snead, 1976; FAO, 2009).

The number of fishery stock assessment and maximum sustainable yield of different fish species have been studied from Pakistani waters like maximum sustainable fishery of Bombay duck and *Saurida tumbil* fishery, *Saurida undosquamis* and *Nemipterus japonicus, N. randalli*, hairtail and *Decapterus russelli* (Kalhoro *et al*., 2013, 2014a, b, 2015a, b, 2017a, b; Memon *et al*., 2015a) but the limited work has been done on the maximum sustainable yield of crab fishery from Pakistani waters, the present work will provide some crab fishery appraisal from Pakistani waters, which may help to sustain the stock level of crab fishery.

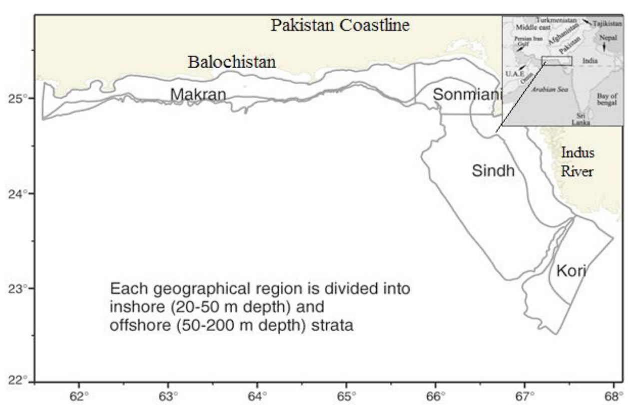

Fig. 1. Pakistan Coastline comprises Sindh and Balochistan coastline at different fish landing sites.

MATERIALS AND METHODS

Fishery statistical data

Fishery annual catch and effort data of *Portunus* spp. from 1999-2009 were obtained from FAO fisheries statistical data (http://www.fao.org/fishery/statistics/en) and handbook of Fisheries Statistics of Pakistan compiled by Marine Fisheries Department (MFD), Karachi (Table I) where fishing efforts was representing the number of fishing boats, and the annual catch were presented in the form of weight (metric ton).

Table I.- Yearly catch and effort data of *Portunus* spp. fishery from Pakistani waters, Northern Arabian Sea.

Year	Effort	Sindh	Baluchistan	EEZ	Total catch
1999	11768	5109	0		5109
2000	12114	5006	0	181	5187
2001	12618	4992	0		4992
2002	12695	4892	0	135	5027
2003	12838	4521	81	17	4619
2004	13002	4901	76	102	5079
2005	13145	4355	65	19	4439
2006	13308	4128	90		4218
2007	13426	3905	143		4048
2008	13522	3688	175		3863
2009	13897	4712	128		4840

Effort, number of fishing boats; EEZ, exclusive economic zone; Total catch in metric tons.

Annual catch and effort data were analyzed by different surplus production models which are Schaefer, Fox and Pella-Tomlinson which were available into two computer program CEDA (catch effort data analysis) (Hoggarth *et al*., 2006) and ASPIC (a surplus production models incorporating covariates) (Prager, 2005)

$$dB / dt = rB(B_{\infty} - B) \quad \text{(Schaefer, 1954)}$$

Later work of Fox (1970) put forward a Gompertz growth equation, and another work from Pella and Tomlinson (1969) reported a generalized production equation:

$$dB / dt = rB(InB_{\infty} - InB) \quad \text{(Fox, 1970)}$$

$$dB / dt = rB(B_{\infty}^{n-1} - B^{n-1}) \quad \text{(Pella and Tomlinson, 1969)}$$

Where, B is fish stock biomass, t is time (year), B_{∞}, is carrying capacity, r is intrinsic rate of population increase and n is the shape parameter.

$$B_{t+1} = B_t + rB_t(B_{\infty} - B_t) - C_t$$

$$C_t = qE_tB_t$$

Where, C is catch, q is catchability, E is the fishing efforts. Fishing mortality can then be calculated as:

$$F = qE$$

CEDA (catch and effort data analysis)

CEDA (Hoggarth *et al*., 2006) is computer base programming which is built on non-equilibrium surplus production models Schaefer, Fox and Pela and Tomlinson with three error assumptions (normal, lognormal and gamma) with output parameters were: MSY (maximum sustainable yield), *K* (carrying capacity), *q* (catchability coefficient), *r* (intrinsic growth rate), R_{yield} (replacement yield) and final biomass. The non-equilibrium surplus productions models were mostly used and it was assumed and fishery stock is not in equilibrium state because ecological, environmental and fishing efforts factors also affect the fishery stock and fishery stock will not in equilibrium state in that case non-equilibrium surplus production models were frequently used for stock assessment for better fishery management.

ASPIC (a surplus production models incorporating covariates)

ASPIC is non-equilibrium surplus production model and have two models; Logistic (Schaefer) and Fox model, ASPIC output parameters are: MSY, *q*, *K*, ration of the starting biomass over carrying capacity B_1/K coefficient of determination (R^2), coefficient of variation (CV), stock biomass in giving MSY (B_{MSY}), and fishing mortality rate at MSY (F_{MSY}). The initial proportion (IP) of B_1/K (Starting biomass over carrying capacity) is input values by users, it was assumed that when IP is close to zero, this indicates that the data are from virgin population, and if IP is close to one it means the data starts from fully developed state (Prager, 2005).

RESULTS

CEDA

CEDA (catch and effort data analysis) computer software package shows sensitive with different IP values, different IP values and results are showing in Table II, gamma error assumptions of those three models mostly gives minimization failure (MF) it also shows that the values obtained from Schaefer (1954) and Pella and Tomlinson (1969) with all those error assumptions (normal, lognormal and gamma) were same. To estimate MSY value in present study IP value 0.9 were used because the starting catch was roughly 90% of the maximum catch which were calculate first year catch divided by maximum catch of those years, the estimated value from calculate IP (0.9) from Fox with three error assumptions (normal, lognormal and gamma) were 3378 R^2 (R^2 =0.590), 3360 (R^2=0.582), 3369 (R^2=0.586), respectively (Table III, Fig. 2), whereas, the obtained values from Schaefer (1954) and Pella and Tomlinson (1969) with two error assumptions (normal and lognormal) were 2878 (R^2=0.587), 3035 (R^2=0.578) and gamma were minimization failure (MF) in both models.

ASPIC

Output values from both Fox and logistic model are showing in Table IV using different IP values from 0.2-1, shows that ASPIC package is not sensitive with using different IP values. The MSY value from IP value 0.9 was obtained to set the level of fishery status because the initial yield was about 90% of the maximum catch. The estimated MSY value from Fox model were 3652 (R^2 =0.8) with 0.183 coefficient of variation (CV) (Table V), overall values from 0.2-1 IP value estimated in fox models were range from 3650-3658 with R^2 = 0.8, which shows the accuracy of data and best fit of the model showing the goodness of fit. Whereas, the MSY value from calculate IP (0.9) from logistic model were 2962 (R^2 =0.799) with 0.199 CV (Table V), overall MSY values using

Table II.- MSY appraisal of *Portunus* spp. from CEDA package using different IP values from 0.2-0.9 from Pakistani waters, Northern Arabian Sea.

IP	Models FOX			Schaefer			Pella-Tomlinson		
	Normal	Log-normal	Gamma	Normal	Log-normal	Gamma	Normal	Log-normal	Gamma
0.2	5268	4605	MF	MF	5229	MF	MF	5229	MF
0.3	4228	3866	4217	MF	5914	5919	MF	5914	5919
0.4	3727	3580	3720	5103	5052	5061	5104	5052	5061
0.5	3460	3568	3455	4119	4215	4109	4119	4215	4109
0.6	3326	3547	3319	3595	3505	MF	3595	3505	MF
0.7	3278	3495	3267	3256	3442	3252	3256	3442	3252
0.8	3297	3551	MF	3028	3289	3026	3028	3289	3026
0.9	3378	3360	3369	2878	3035	MF	2878	3035	MF

CEDA, catch and effort data analysis; IP, initial proportion; MF, minimization failure; MSY, maximum sustainable yield.

Table III.- Outcomes value of *Portunus* spp. from CEDA package using IP value 0.9 because the initial catch were 90% of the maximum catch.

Model	K	r	MSY	R_{yield}	q	R^2	Biomass
Fox (normal)	97129	0.094	3378	2812	5.19E-06	0.590	58330
Fox (Log normal	95855	0.095	3360	2814	5.26E-06	0.582	57199
Fox (Gamma)	95574	0.095	3368	2821	5.29E-06	0.586	57016
Schaefer (normal	92352	0.124	2878	2764	5.45E-06	0.587	55354
Schaefer (Log normal)	83687	0.145	3035	2938	6.08E-06	0.578	49304
Schaefer (Gamma)	MF	MF	MF	MF	MF	MF	MF
Pella Tomlinson (Normal)	92352	0.124	2878	2764	5.45E-06	0.587	55354
Pella Tomlinson (Log normal)	83687	0.145	3035	2938	6.08E-06	0.578	49304
Pella Tomlinson (Gamma)	MF	MF	MF	MF	MF	MF	MF

For abbreviations, see Table II.

Table IV.- ASPIC outcomes for the *Portunus* spp. fishery using IP values from 0.2-1 from Pakistani waters, Northern Arabian Sea.

Model	IP	MSY	B_1/K	K	q	F_{MSY}	R^2	CV	B_{MSY}
	0.2	3658	1.00	95220	4.78E-06	0.104	0.8	0.127	35030
	0.3	3655	1.00	95210	4.79E-06	0.104	0.8	0.133	35030
	0.4	3658	1.00	95210	4.78E-06	0.104	0.8	0.135	35020
	0.5	3655	1.00	95200	4.79E-06	0.104	0.8	0.151	35020
FOX	0.6	3653	1.00	95240	4.78E-06	0.104	0.8	0.167	35040
	0.7	3650	1.00	95260	4.78E-06	0.104	0.8	0.131	35050
	0.8	3660	1.00	95200	4.78E-06	0.104	0.8	0.125	35020
	0.9	3652	1.00	95240	4.79E-06	0.104	0.8	0.183	35040
	1.0	3657	1.00	95200	4.79E-06	0.104	0.8	0.157	35020
	0.2	5270	0.367	24470	4.93E-05	0.430	0.794	0.968	12230
	0.3	5147	0.429	8857	0.000121	1.162	0.741	0.059	4428
	0.4	2958	1.00	92570	4.92E-06	0.063	0.799	0.153	46290
LOG	0.5	2959	1.00	92700	4.91E-06	0.063	0.799	0.124	46350
	0.6	2972	1.00	92340	4.93E-06	0.064	0.799	0.172	46170
	0.7	2960	1.00	92510	4.93E-06	0.064	0.799	0.148	46250
	0.8	2951	1.00	92820	4.9E-06	0.063	0.799	0.170	46410
	0.9	2962	1.00	92500	4.93E-06	0.064	0.799	0.199	46250
	1.0	2954	1.00	92740	4.91E-06	0.063	0.799	0.166	46370

IP, initial proportion; MSY, maximum sustainable yield; B_1/K, starting biomass; *K,* carrying capacity; q, catchability coefficient; F_{MSY}, fishing mortality rate at MSY; R^2, coefficient of determination; CV, coefficient of variation, B_{MSY}, stock biomass in giving MSY.

Table V.- ASPIC results with 0.9 IP (initial proportion) value for the *Portunus* spp. fishery from Pakistani waters, Northern Arabian Sea.

Model	IP	MSY	B_1/K	K	q	F_{MSY}	R^2	CV	B_{MSY}
FOX	0.9	3652	1	95200	4.8E-06	0.1044	0.8	0.183	35020
LOGISTIC	0.9	2962	1	92500	4.9E-06	0.0641	0.799	0.199	46250

For abbreviations, see Table IV.

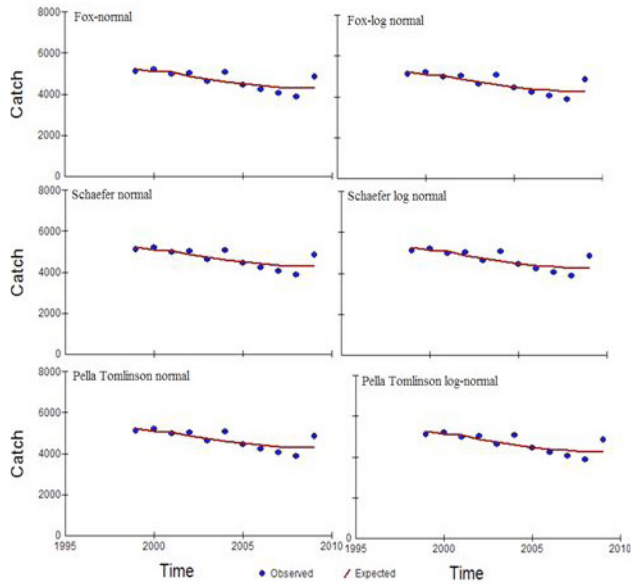

Fig. 2. Catches from three production models from 0.9 IP value where observed (dots) and expected (lines) from Fox, Schaefer and Pella Tomlinson models from CEDA package during 1999-2009 fishery from Pakistani waters, Northern Arabian Sea.

different IP values (0.2-1) from logistic model were 2151-5270 Table IV. The confidential interval is also easy to estimate using bootstrapping method which provides 95% confidential interval and overall values were lower than 0.2.

DISCUSSION

Catch and efforts data is mostly used to calculate MSY for better stock assessment for any fishery where catch should be yearly or monthly and efforts must be in number of fishing boats, number of fishermen engaged in that time period or number of fishing hours in that fishing time, in present study the yearly catch and number of fishing boats were used to estimate the MSY value for crab fishery from Pakistani waters, Northern Arabian Sea. The surplus production models are much more helpful to estimate the MSY and optimal level of efforts that produces the MSY and is always considered as target biological reference point (BRP) from which sustainable fishery management goals can be achieved (Hilborn and Walters, 1992). Earlier studies were based on equilibrium production models but stocks are seldom in equilibrium state due to some biological, environmental factors and unmanaged fishing mortality which effects the population in this case non-equilibrium surplus production models are frequently used to know the state of stock. The surplus production models can give idea about the stock because they do not require and environmental data (Quinn and Deriso, 1999) The surplus production models were frequently used for fishery management since last decades and recently were also used for Pakistani waters (Kalhoro *et al*., 2013, 2015; Soomro *et al*., 2015a, b; Memon *et al*., 2015a, b).

The overall results from CEDA and ASPIC surplus production models were almost equal or same using different IP values, the concept of the MSY is if MSY estimated value is greater than recent catch then it shows that the fish stock is in safe condition, but when the estimated MSY value equals to annual catch it may be assumed that fish population in in sustainable state, however, if the estimated MSY value from different surplus production models is smaller than annual catch it indicates that the stock of fishery is over-exploitation state. In the present study using different surplus production models results shows that the estimated MSY values (Tables II, III, IV, V) is smaller than annual catch. Table I shows that the stock of swimming crab fishery from Pakistani waters was in overexploitation state. In the light of present study, we may suggest that take some management steps to reduce the fishing efforts for crab fishery, protect the nursery grounds of the crab fishery to maintain the stock of crab fishery from Pakistani waters.

CONCLUSION

Maximum sustainable yield (MSY) estimated from both computer packages CEDA and ASPIC results were close and give value smaller than annual catch of the swimming crab fishery which indicates that the stock of crab fishery from Pakistani waters is in overexploitation state. We may suggest that fishery managers take some management steps like reduce the fishing efforts, declare Marine Protected Area at nursery grounds of fin and shellfish, generally due to freshwater inflow from Indus River creates rich mangrove ecosystem from Sindh area so it is considered to be best nursery grounds for fish and shellfish, monitoring the trawl mesh size, ban period during the breeding season of crab fishery to sustain the crab fishery stock from Pakistani waters, Northern Arabian Sea.

ACKNOWLEDGMENTS

Present study is supported by research project awarded to Prof. Dr. DanLing Tang: 1) Key project, “Marine phytoplankton size classes and related ecological factors respond to typhoons - based on remote sensed and in situ data” awarded by National Natural Sciences Foundation of China (41430968); 2) Collaborative

Innovation Center for 21st-Century Maritime Silk Road Studies, Guangzhou, China (2015HS05). First author also thankful to China Postdoctoral fellowship program by South China Sea Institute of Oceanology, Chinese Academy of Sciences (158563) and China Science and Technology Exchange Center, Ministry of Science and Technology for awarding Talented Young Scientist Award (PAK-16-021) recommended by Ministry of Science and Technology Pakistan.

Statement of conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Afzaal, Z., Kalhoro, M.A., Buzdar, M.A., Nadeem, A., Saeed, F., Haroon, A. and Ahmed, I., 2016. Stock Assessment of Blue Swimming Crab *Portunus pelagicus* (Linnaeus, 1758) from Pakistani Waters (Northern, Arabian Sea). *Pakistan J. Zool.,* **48**: 1531-1541

Apel, M. and Spiridonov, V.A., 1998. Taxonomy and zoogeography of the portunid crabs (Crustacea: Decapoda: Brachyura: Portunidae) of the Arabian Gulf and adjacent waters. *Fauna of Arabia*, **17**: 159-331.

Edgar, G.J., 1990. Predator-prey interactions in sea grass beds. II. Distribution and diet of the blue manna crab *Portunus pelagicus* Linnaeus at Cliff head, Western Australia. *J. exp. Mar. Biol. Ecol.,* **139**: 23-32. https://doi.org/10.1016/0022-0981(90)90035-B

FAO. 2009. *Fishery and aquaculture profile*. FAO's Fishery Department, Rome, Italy, 00.1-18.

Fox, W.W. Jr., 1970. An exponential surplus-yield model for optimizing exploited fish populations. *Trans. Am. Fish. Soc.,* **99**: 80-88. https://doi.org/10.1577/1548-8659(1970)99<80:AESMFO>2.0.CO;2

Hilborn, R. and Walters, C.J., 1992. *Quantitative fisheries stock assessment, choice, dynamics and uncertainty*. Chapman and Hall, New York, London. https://doi.org/10.1007/978-1-4615-3598-0

Hoggarth, D.D., Abeyasekera, S., Arthur, R.R.I., Beddington, J.R., Burn, R.W., Halls, A.S., Kirkwood, G.P., McAllister, M., Medley, P., Mess, C.C., Parkes, G.B., Pilling, G.M., Wakeford, R.C. and Welcome, R.L., 2006. Stock assessment of fishery management- A framework guide to the stock assessment tools of the fishery management science programme. FAO Fisheries Technical Paper, 487, FAO, Rome, Italy, pp. 261.

Kailola, P.J., Qilliams, M.J., Stewart, P.C., Reichelt, R.E., Mcnee, A. and Grieve, C., 1993. *Australian fisheries resources*. Bureau of Resources Sciences, Department of Primary Industries and Energy and the Fisheries Research and Development Corporation, Canberra, Australia.

Kalhoro, M.A., Liu, Q., Memon, K.H., Chang, M.S. and Jatt, A.N., 2013. Estimation of maximum sustainable yield of Bombay duck, *Harpodon nehereus* fishery in Pakistan using the CEDA and ASPIC packages. *Pakistan J. Zool.,* **45**: 1757-1764.

Kalhoro, M.A., Liu, Q., Valinassab, T., Waryani, B. Abbasi, A.R., Memon, K.H., 2015a. Population dynamics of Greater Lizardfish, *Saurida tumbil* from Pakistani waters. *Pakistan J. Zool.,* **47**: 921-931.

Kalhoro, M.A., Liu, Q., Waryani, B., Panhwar, S.K., Memon, K.H., 2014a. Growth and mortality of brushtooth lizardfish *Saurida undosquamis* from Pakistani waters. *Pakistan J. Zool.,* **46**: 139-151.

Kalhoro, M.A., Liu, Q., Memon, K.H., Chang, M.S. and Zhang, K., 2014b. Population dynamics of Japanese threadfin bream *Nemipterus japonicus* from Pakistani waters. *Acta Oceanol. Sin.,* **33**: 1-9. https://doi.org/10.1007/s13131-014-0401-1

Kalhoro, M.A., Liu, Q., Memon, K.H., Waryani, B. and Soomro, S.H., 2015b. Maximum sustainable yield of Greater lizardfish *Saurida tumbil* fishery in Pakistan using CEDA and ASPIC packages. *Acta Oceanol. Sin.,* **34**: 68-73. https://doi.org/10.1007/s13131-014-0463-0

Kalhoro, M.A., Tang, D., Ye, H.J, Morozov, E., Liu, Q., Memon, K.H. and Kalhoro, M.T., 2017a. Population dynamics of Randall's threadfin bream *Nemipterus randalli* from Pakistani waters, Northern Arabian Sea. *Indian J. Mar. Sci.,* **46**: 551-561.

Kalhoro, M.T., Yongtong, M., Kalhoro, M.A., Mahmood, M.A., Hussain, S.S.B., Muhammad, M. and Tushar, P.R., 2017b. Stock assessment of Indian Scad, *Decapterus russelli* in Pakistani marine waters and its impact on the national economy. *Fish Aqua. J.*, **8**: 1-10

Kazmi, Q.B., 2003. *Taxonomic studies of Crustaceans in Pakistan. Global Taxonomy Initiative in Asia*. Report and Proc. 1st GIT Regional Workshop in Asia Putrajaya, Malaysia. (J. Shimura, Ed.). Natl. Inst. Environ. Studies, Japan No.175: 230-248.

Mace, P.M., Bartoo, N.M., Hollowed, A.B., Kleiber, P., Methot, R.D., Murawski, S.A. and Scott, G.P., 2001. *National marine fisheries services stock assessment improvement plan. Report of the NMFS National*

Task Force for Improving Fish Stock Assessment. NOAA Technical Memorandum NMFS-F SPO-56. pp. 76.

Memon, A.M., Liu, Q., Memon, K.H., Baloch, W.A., Memon, A. and Baset, A., 2015a. Evaluation of the fishery status for King Soldier Bream *Argyrops spinifer* in Pakistan using the software CEDA and ASPIC. *Chinese J. Oceanol. Limnol.,* **33**: 966-973. https://doi.org/10.1007/s00343-015-4330-4

Memon, K.H., Liu, Q., Kalhoro, M.A., Chang, M.S. and Jatt, A.N., 2015b. Maximum sustainable yield estimates of the Barramundi *Lates calcarifer* Fishery from Northern Arabian Sea. *Indian J. mar. Sci.,* **44**: 12-18.

Memon, K.H. Liu, Q., Kalhoro, M.A. Chang, M.S., Liao, B., Memon, A.M., Hyder, S. and Tabassum, T., 2016. Growth and mortality parameters of hairtail *Lepturacanthus savala* from Pakistani waters. *Pak. J. Zool.,* **48**: 829-837.

Pella, J.J. and Tomlinson, P.K., 1969. A generalized stock production model. *Bull. Inter-Am. Trop. Tuna Comm.,* **13**: 421-496.

Potter, I.C., Chrystal, P.J. and Loneragan, N.R., 1983. The biology of the blue manna crab *P. pelagicus* in the Australian estuary. *Mar. Biol.,* **78**: 75-85. https://doi.org/10.1007/BF00392974

Prager, M.H., 2005. *A stock-production model incorporating covariates (version 5) and auxiliary programs*. CCFHR (NOAA) Miami Laboratory Document MIA-92/93-55, Beaufort Laboratory Document BL-2004-01.

Quinn, T.J. and Deriso, R.B., 1999. *Quantitative fish dynamics*. Oxford University Press, USA, pp. 542.

Rasheed, S. and Mustaquim, J., 2010. Size at sexual maturity, breeding season and fecundity of three-spot swimming crab *Portunus sanguinolentus* (Herbst, 1783) (Decapoda, Brachyura, Portunidae) occurring in the coastal waters of Karachi, Pakistan. *Fish. Res.,* **103**: 56-62. https://doi.org/10.1016/j.fishres.2010.02.002

Schaefer, M.B., 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. *Bull. Inter-Am. Trop. Tuna Comm.,* **1**: 25-56.

Snead, R.R., 1976. Recent morphological changes along the coast of West Pakistan. *Annls. Assoc. Am. Geogr.,* **57**: 550-565. https://doi.org/10.1111/j.1467-8306.1967.tb00621.x

Soomro, S.H., Qun, L., Kalhoro, M.A., Memon, K.H., Zhang, K. and Liao, B., 2015a. Growth and mortality parameters of Indian squid *Uroteuthis* (*Photoligo*) *duvaucelii* (D'Orbigny, 1835) from Pakistani waters (Arabian Sea) based on length frequency data. *Indian J. Geo-Mar. Sci.,* **44**: 1598-1603.

Soomro, S.H., Qun, L., Kalhoro, M.A., Memon, A.M., Shah, S.B., Kalhoro, M.T. and Han, Y., 2015b. Maximum sustainable yield estimates of Indian squid *Uroteuthis* (*photololigo*) *duvaucelii* (D' Ordigny, 1835) from Pakistani waters using ASPIC and CEDA software. *Lasbela Univ. J. Sci. Technol.* **4**: 1-9.

Stephenson, W., 1962. Evolution and ecology of portunid crabs, with special reference to Australian species. In: *The evolution of living organisms* (ed. G.W. Leeper), Melbourne University Press, Melbourne, pp. 311-327.

Sumpton, W.D., Potter, M.A. and Smith, G.S., 1989. The commercial pot and trawl fisheries for sand crabs (*Portunus pelagicus*) in Moreton Bay, Queenland. *Proc. R. Soc. Queensl.,* **100**: 89-100.

Takween, W. and Qureshi, N.A., 2001. Distribution, abundance and diversity indices of Portunid crabs (swimming crabs) from the coastal areas of Pakistan. *Pak. J. mar. Sci.,* **7**: 49-59.

Takween, W. and Qureshi, N.A., 2005. Population structure and reproductive biology of four species of swimming crabs (Crustacea: Brachyura: Portunidae) from coastal area of Karachi, Pakistan. *Pakistan J. mar. Sci.,* **14**: 107-121.