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Contents

English Section

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Diversity and Abundance of the Commercial Fish at Some Coastal Coral Reef Bays in Marsa Alam, Red Sea, Egypt

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Abstract. This work aimed to study the diversity and abundance of the common commercial fish communities at six coastal coral reef bays around Marsa Alam city on the southern coast of the Egyptian Red Sea. Fish communities were counted at six sites, Marsa Saifen, Marsa Shoni2, Marsa Shoni4, Marsa Fujiri, Marsa Nakari and Marsa Hamata using underwater visual census technique (UVC). A total of 2458 fish belonging to 16 families and 44 species of commercial fish were identified. Five families (Scaridae, Serranidae, Mullidae, Lutjanidae and Lethrinidae) contained 27 species (61.4% of the total number of species). Four families (Mullidae, Siganidae, Scaridae and Lutjanidae) were the most abundant and they formed about 91.3% of the total number of recorded individuals. Mullidae was the most abundant constituting about 63.5% of the fish community. The most abundant species was *Mulloidichthys flavolineatus*, of the family Mullidae with 1390 individuals forming 56.5%, followed by *Siganus rivulatus* of the family Siganidae (251, 10.2%). The highest fish abundance was recorded in Marsa Saifen (609 individuals) and the lowest abundance was recorded at Hamata (271 individuals). The highest number of species (23 species) was observed in Marsa Fujiri, whereas the lowest number of species (17 species) was recorded in Hamata. The knowledge of the ecology of marine fish communities in the Red Sea is sparse.Hence, the quantitative ecological studies are needed. Action plans and research programs must be developed to reduce early stages bycatch and initiate fisheries management strategies for commercially exploited species.

Keywords: Commercial reef fish, Bays, Red Sea.

1. Introduction

The world food shortage and the shakable situation of Egyptian food security have made development of our food resources an inevitable necessity. Fish is one of the important traditional components of Egyptian citizen's meal, for its comparative cheap fresh protein (Mohamed *et al*., 2010), and over the years, fish have been considered significant, important, and vital source of world food (protein) (Sharaan *et al*., 2017)

In Egypt, fishery sector is considered as one of the important sectors in the economic structure of the country (Seham & Salem, 2004). Fishing might be known well in ancient Egypt. There are paintings in some tombs of pharaoh's which show fish, probably Tilapia, in man-made pools indicating some type of fish culture (Mcvey, 1994). Fish is a basic

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component of the traditional Egyptian diet and an important source of low-cost animal protein (Soliman & Yacout, 2016). According to the General Authority for Fisheries Resources and Development (GAFRD), fisheries in Egypt are divided into five main areas: the seas, northern lakes, coastal lagoons, inland lakes, and the River Nile (GAFRD 1997–2012).

The Red Sea is a deep semi-enclosed basin connected to the Indian Ocean by a narrow sill in the south (Mandeb Strait) to the Mediterranean Sea by the Suez Canal in the north. The Northern Red Sea is an important sea area, both for fishing and for its unique geography; and often spectacular marine ecology as macro-algae, sea-grass beds, mangroves, and coral reefs (Alkershi & Menon, 2011). The Red Sea has long been recognized as a region of high biodiversity (Samy *et al*., 2011).

The Red Sea coast of Egypt, including the Gulfs of Suez and Aqaba and the intervening Sinai Peninsula, about 1500 km in length (Bird, 2010). The delicate area of the Egyptian Red Sea coast contains about 66% of hard coral reefs species existing within the Red Sea including some endemic species (PERSGA, 2009-2010). Moreover, Coral reefs provide protection and shelter in the natural zone for many different species of fish, and home to over 1000 species, many of them with commercial value. Red Sea is one of the most important fishery resources in Egypt. It has many commercial fish species which are more common in the tropical and subtropical Indo-West Pacific area. On the other hand, these species are absent in the eastern Pacific and Atlantic oceans (Russell, 1990; El-Ganainy, *et al*., 2018). They are consumed as food by some larger fish, which are in turn consumed by humans through the food chain (Altndag & Yigit, 2005 and Abdel Gawad, 2018).

Coastal systems provide important ecosystem services with considerable economic and ecological value (Lotze *et al*., 2006; Barbier *et al*. 2011), and play an important role as nursery and fishing grounds for many commercial species (Ahmed & El-Mor, 2006). The Red Sea contains many coastal bays, which act as nursery areas for many commercial and recreationally harvested fish species (Morsy, *et al*., 2010; Mustafa, *et al*., 2014; Peters & Chigbu, 2017). Coastal fish are defined as fish assemblages in shallow near-shore areas (less than 20 m depth). Coastal fish are also of importance for environmental management from several perspectives. They contribute to human well-being both directly via commercial and recreational fisheries, and by supporting the functioning of coastal food webs (Ronnback *et al*., 2007; Seitz *et al*., 2014). For example, coastal fish provide a food source for other species (top predators, piscivorous fish) and act as consumers potentially regulating the abundance of lower trophic level taxa (Ostman *et al*., 2016).

The abundance and species composition of coastal fish assemblages may be locally influenced not only by, for example, the availability of recruitment and foraging areas, prey availability and predation patterns (Harma *et al*., 2008; Vetemaa *et al*., 2010; Ostman *et al*., 2012; Sundblad *et al*., 2014), but also by anthropogenic stressors, such as eutrophication and fishing pressure (Bergstrom *et al.*, 2013; Florin *et al.*, 2013; Mustamaki *et al.*, 2014; Snickars *et al.*, 2015, Bergstrom *et al.*, 2016).

Stock assessments studies over the last 10 years showed that most commercial fish species in the Red Sea and Mediterranean Sea were subject to overfishing (Maiyza *et al*., 2020; Al Solami, 2020 and Shalem *et al*., 2021); Emperor fish, *Lethrinus lentjan* (Younis *et al*., 2020); rabbit fish, *Siganus rivulatus* (Mehanna *et al*., 2018; Gabr *et al*., 2018); bogue, *Boops boops* (Azab *et al*., 2019); Red Sea goatfish, *Parupeneus forsskali* (Sabrah, 2015); lizard fish, *Saurida undosquamis* (El-Etreby *et al*.,

2013) and round sardin, *Sardinella aurita* (Mehanna & Salem, 2012).

There is a shortage of information on fisheries biology and population dynamics in the Red Sea (Sabrah, 2015). Management of fisheries required detailed data on the fleets and exploited resources. Such information should indicate the status of each fishery, their dynamics, characteristics, as well as temporal and spatial distribution of each fleet (Forcada *et al*., 2010; Samy-Kamal *et al*., 2014). The future of fisheries in Egypt also relies in improving the current management strategies and measures. It is important to evaluate the effectiveness of management measures (Samy-Kamal *et al*. 2015a, b & c) to understand if they can achieve their main objectives.

Marsa Alam is a popular and well-known diving destination and renowned seaside resort after being a humble fishing village on the southern border of the Egyptian Red Sea. The city has gained international recognition, welcoming visitors from around the globe to enjoying diving and snorkeling in its fascinating reefs and colorful creatures. The coast of Marsa Alam is characterized by lots of shallow coastal reef bays that harbor hundreds of coral reef fish species of which many are commercial and used as food. The aim of this survey is to spotlight the status of the existing commercial fish in six bays around Marsa Alam City located on the sensitive environmental zone of the Red Sea coast of Egypt.

2. Materials and Methods

3.1 Study Area and Data Collection

The studied area covered the zone around Marsa Alam City, including six bays (Fig.1, Table1). Within this area, commercial fish checklists were obtained and grouped.

The underwater visual census technique (UVC) of the reef fishes is used as a method to record the occurrence and abundance of fish species. Fish were counted visually using transect method where the diver swim slowly along 100 m long, counting fishes at 5 m wide and 1 m high transect. On average about 100 m was covered in 10 minutes -swimming period.

Fish were identified up to species level using the underwater identification guide of Randall (1992). Individuals of each species were separately counted, and their abundances were recorded on the underwater data sheets (Zekeria *et al*., 2002). Checklists of reef fish were extracted from the literature (Bellwood & Hughes, 2001 and Mora *et al*., 2012) and from FISHBASE (Froese & Pauly, 2003). These lists were completed with recent reviews of fish families or genera.

2.2 Data Analysis

The univariate statistics were done in SPSS 22, using ANOVA to determine differences in number of individuals and number of species among different months and bays. All data were tested for homogeneity of variance. If samples were not homogeneous, data were either transformed or the non-parametric Kruskal-Wallis test was used (Zar, 1996; Dytham, 2003).

The multivariate cluster analysis was used to determine similarities between sites and months, and diversity indices (species richness, the evenness, Shannon-Wiener and Simpson's index) were calculated using PRIMER (Plymouth Routines in Multivariate Ecological Research) version 6.

3. Results

3.1 General Abundance of Commercial Reef Fish

The visual censuses recorded 14353 fish belonging to 133 fish species of which 2458 individuals representing 16 families and 44 species are commercially important and used as food. Commercial fish formed about 17% of the whole fish community in the area (Fig. 2). The highest number of fish individuals was recorded at Marsa Saifen, where 609 fish were counted; followed by Marsa Fujiri (496 fish) and Marsa Shoni2 (463 fish). The lowest number of fish individuals was found at Marsa Hamata, where only 271 fish were recorded (Table, 3 and Fig. 3).

The results showed that Marsa Fujiri recorded the highest diversity with 23 species (52.3% of the total number of collected commercial reef fish species), followed by both the bays of Shoni2 and Shoni4 with 21 species (47.7%). On the other hand, Hamata had only 38.6% (17 species) of the collected commercial fish species (Table, 2).

3.2 *Species Composition of Commercial Fish Community*

A total of 16 families and 44 species of commercial fish were recorded in the six surveyed bays. The family Scaridae was the most diverse family with eight species followed by Serranidae and Mullidae which included six and five species, respectively. Each of Lutjanidae and Letherinidae had four species. On the other hand, six fish families (Hemiramphidae, Nemipteridae, Kyphosidae, Priacanthidae, Scombridae and Platycephallidae) were represented by only one species (Table, 2).

Four families (Mullidae, Siganidae, Scaridae and Lutjanidae) were the most abundant and they formed about 91.3% of the total number of recorded individuals. The most abundant family was Mullidae, which contained 1561 individuals (63.5% of the total number of individuals). The lowest abundant five families were Kyphosidae, Synodontidae. Priacanthidae, Heamulidae and Platycephalidae; they contributed less than 1% of the total number of individuals (Table, 2 and Fig. 4).

Six species formed about 83.8% of all counted fishes. Where the most abundant species was *Mulloidichthys flavolineatus* (Family: Mullidae), with 1390 fish recorded (constituting 56.55 % of all fish community). The second most abundant species was *Siganus rivulatus* (Family: Siganidae) with 251 individuals forming 10.21% of all fish number. The third most abundant species, *Lutjanus monostigma* (Family: Lutjanidae), formed 6.79% of all fish (167 fish). The fourth abundant species was *Mulloidichthys vanicolensis* (Family: Mullidae) with 122 fish (represented 4.96% of all fish number followed by *Scarus niger* and *Chlorurus sordidus* (Family: Scaridae) with 68 and 62 fish forming 2.77% and 2.52% of all fish number, respectively (Table, 3 and Fig. 5).

Results showed that 7 commercial fish species (*Hipposcarus harid*, *Calotomus viridescens*, *Parupeneus forsskali*, *Lutjanus kasmira*, *Gerres longirostris*, *Hemiramphus far* and *Rastrelliger kanagurta*) had a moderate level of abundance. These species formed about 8.7 % of the total number of fish. On the other hand, 31 commercial fish species were rare and collectively constituted only 7.5 % of the total number of specimens (Table, 3 and Fig. 5,6).

3.3 Diversity and Abundance in Different Coastal Bays of Marsa Alam

Out of 44 species recorded, three species representing 64.27 % of the total commercial fish abundance (*Mulloidichthys flavolineatus*, *Parupeneus forsskali* from family Mullidae and *Scarus niger* from family Scaridae) were recorded from all sites, and three species (14.24 % of commercial fish abundance) (*Chlorurus sordidus*, *Hipposcarus harid* from family Scaridae and *Siganus rivulatus* from family Siganidae) were occurred at five ones. Whereas 14 species (7.97 %) were recorded from only one site (Table, 3).

3.4 Diversity and Abundance in Different Coastal Bays of Marsa Alam

Diversity indices varied considerably among bays. Richness varied from the minimum value of 2.81 in Saifen to the maximum of 3.54 in Fujiri. The Evenness value ranged from the lowest of 0.37 in Saifen to the highest of 0.72 in Shoni4. The highest value of diversity index (Shannon-Wiener) was recorded also in Shoni4; and the lowest value was found in Saifen. The highest value of Simpson's index was recorded in Shoni4, and the lowest value was recorded in Saifen (Fig. 7).

The analysis of variance (ANOVA) showed that abundance of fish in different bays were not significantly different ($F= 2.72$, $P>0.05$). Whereas there was a significant difference in number of species among bays ($F= 6.102$, $P<0.05$). Fujiri was significantly varied from other bays in the survey.

Depending on the number of individuals at different bays, the similarity index showed that they could be divided into two main clusters with similarity of 60% (Fig. 8,9). The first cluster contained three bays (Shoni4, Hamata, and Nakari). With a maximum similarity between stations Shoni4 and Hamata (99.18), the similarity between them and Nakari was 95.22. The second cluster included the rest of bays (Fujiri, Shoni2, and Saifen). With a maximum similarity between stations Fujiri and Shoni2 (98.28), the similarity between them and Saifen was 94.87. Also, the similarity between the two clusters was high (92.22).

Depending on the number of individuals at different bays, it could be divided into two clusters. The first cluster contains two bays (Fujiri and Nakari), with maximum similarity between them (Fig. 8). The second cluster also includes two bays (Shoni2, and Shoni4), with a maximum similarity (68.44), the similarity between the two clusters was 63.73. The similarity between the two clusters and Saifen was slightly low (55.91). The similarity between the previous bays and Hamata was (50.53) (Fig. 8).

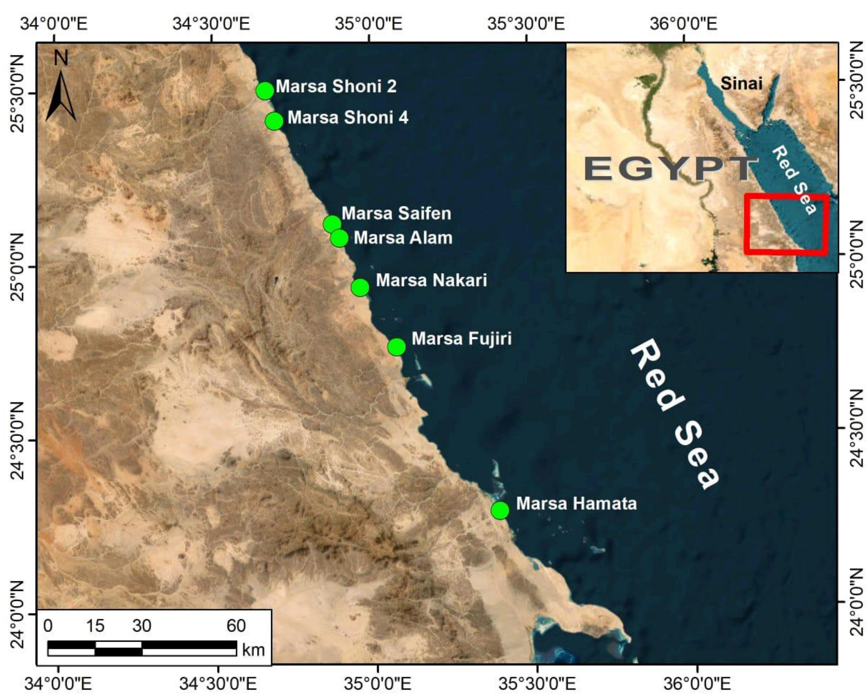

Fig. 1. Map of the study area and survey sites.

Table 1. Coordinates of the surveyed bays along Marsa Alam coast, Red Sea.

Sites	Latitude	Longitude
Marsa Shoni2	25°30'2.38"N	34°40'8.44"E
Marsa Shoni4	25°25'4.01"N	34°41'40.46"E
Marsa Saifen	25° 6'18.05"N	34°52'52.19"E
Marsa Nakari	24°55'34.90"N	34°57'45.61"E
Marsa Fujiri	24°45'21.39"N	35° 4'4.24"E
Marsa Hamata	24°17'15.18"N	35°22'49.93"E

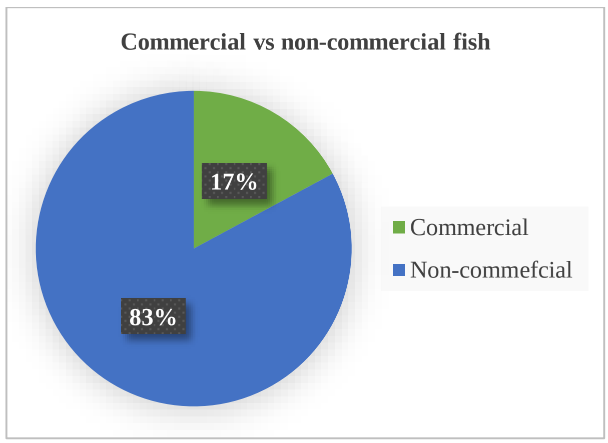

Fig. 2. The percentage contribution of commercial vs non-commercial fish species along Marsa Alam, Red Sea.

Table 2. Diversity and abundance of commercial fish families in the study area.

Families	No. of species	Abundance	
		No.	%
Mullidae	5	1561	63.5
Siganidae	3	259	10.5
Scaridae	8	221	9.0
Lutjanidae	4	203	8.3
Scombridae	1	45	1.8
Gerridae	2	42	1.7
Lethrinidae	4	28	1.1
Serranidae	6	24	1.0
Hemiramphidae	1	20	0.8
Carangidae	2	17	0.7
Nemipteridae	1	15	0.6
Kyphosidae	1	10	0.4
Synodontidae	2	5	0.2
Priacanthidae	1	4	0.2
Heamulidae	2	3	0.1
Platycephallidae	1	1	0.0
Total	**44**	**2458**	**100.0**

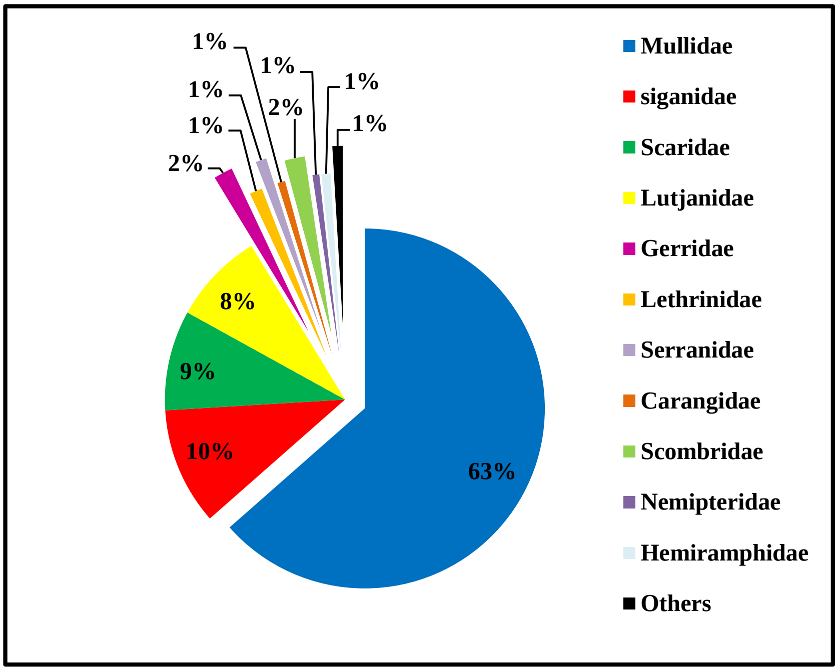

Fig. 3. Abundance of commercial reef fish families in coastal bays along Marsa Alam, coast, Red Sea.

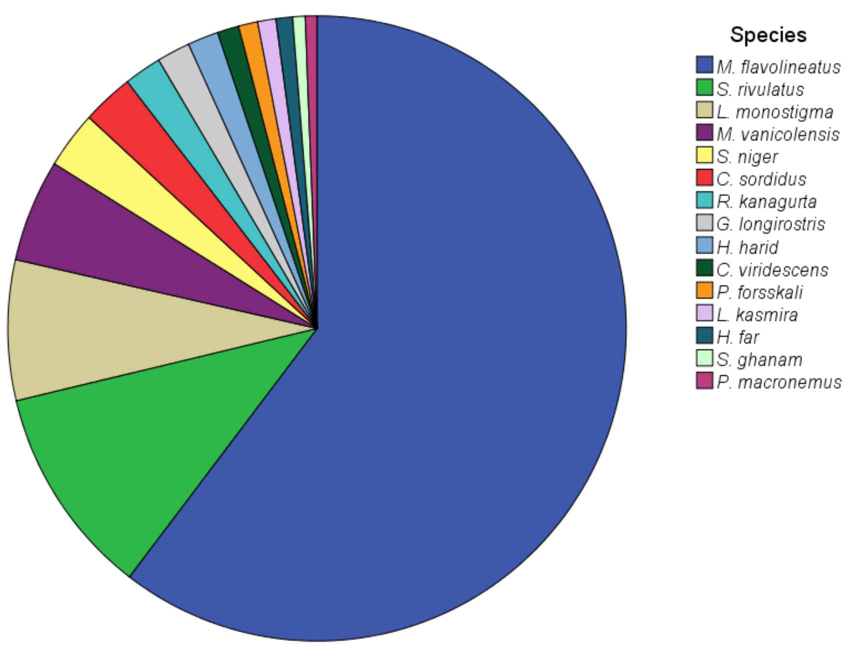

Fig. 4. Percentage contribution of the most abundant species in coastal bays along Marsa Alam, coast, Red Sea.

Table 3. Abundance of the commercial reef fish species in the different studied coastal bays of Marsa Alam, Red Sea, Egypt.

Family	Species	Saifen	Fujiri	Shoni2	Shoni4	Nakari	Hamata	Total
Scaridae	*Scarus niger*	10	7	24	15	8	4	68
	Chlorurus sordidus	6	14	20	13	9		62
	Chlorurus gibbus						1	1
	Hipposcarus harid	6	15		8	3	5	37
	Calotomus viridescens		3	11	12			26
	Scarus frenatus	3	3	2		3		11
	Scarus ferrugineus		2	4		3	1	10
	Cetoscarus bicolor	2			4			6
Serranidae	*Variola louti*	1		1	1			3
	Cephalopholis miniata			1	1	3		5
	Cephalopholis argus	3	1	2	2			8
	Cephalopholis hemistiktos		2	3		1		6
	Epinephelus tauvina						1	1
	Epinephelus summana						1	1
Mullidae	*Mulloidichthys flavolineatus*	418	324	236	104	158	150	1390
	Mulloidichthys vanicolensis	122						122
	Parupeneus macronemus	3	3	2			6	14
	Parupeneus cyclostomus		5	2	2	3		12
	Parupeneus forsskali	3	8	2	3	3	4	23
Lutjanidae	*Lutjanus monostigma*		10	107	40	10		167
	Lutjanus bohar	1	1		1			3
	Macolor niger	1	2		7	1		11
	Lutjanus kasmira	19	3					22
Lethrinidae	*Monotaxis grandoculis*		3	3	2			8
	Lethrinus harak		2		7		1	10
	Lethrinus nebulosus		5					5
	Lethrinus mahsena						5	5
Siganidae	*Siganus luridus*			3	3			6
	Siganus stellatus			2				2
	Siganus rivulatus		54	25	34	97	41	251
Carangidae	*Caranx melampygus*	4						4
	Carangoides bajad	3	8			2		13
Heamulidae	*Plectorhinchus schotaf*				1			1
	Plectorhinchus gaterinus	1					1	2
Gerridae	*Gerres longirostris*						40	40
	Gerres oyena					2		2
Synodontidae	*Synodus variegatus*	1				2		3
	Saurida gracilis	2						2
Hemiramphidae	*Hemiramphus far*			5	10	5		20
Nemipteridae	*Scolpsis ghanam*		1	7		1	6	15
Kyphosidae	*Kyphosus vaigiensis*				10			10
Priacanthidae	*Priacanthus hamrur*			1			3	4
Scombridae	*Rastrelliger kanagurta*		20			25		45
Platycephallidae	*Papilloculiceps longiceps*						1	1
Total diversity	Number	19	23	21	21	19	17	44
	%	43.2	52.3	47.7	47.7	43.2	38.6	100
Total abundance	Number	609	496	463	280	339	271	2458
	%	24.8	20.2	18.8	11.4	13.8	11.0	100

Highly Abundant (orange) — Moderately abundant (green) — Less abundant (white)

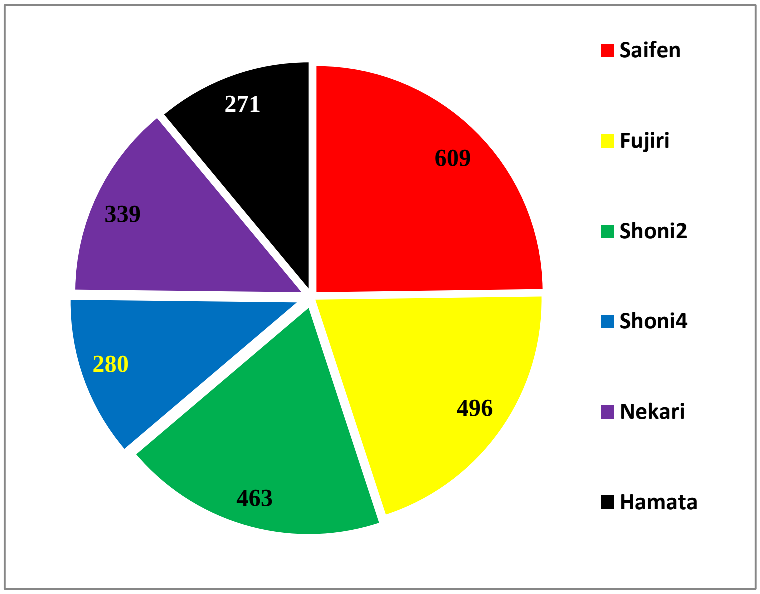

Fig. 5. Abundance of commercial reef fish at different bays along Marsa Alam coast, Red Sea.

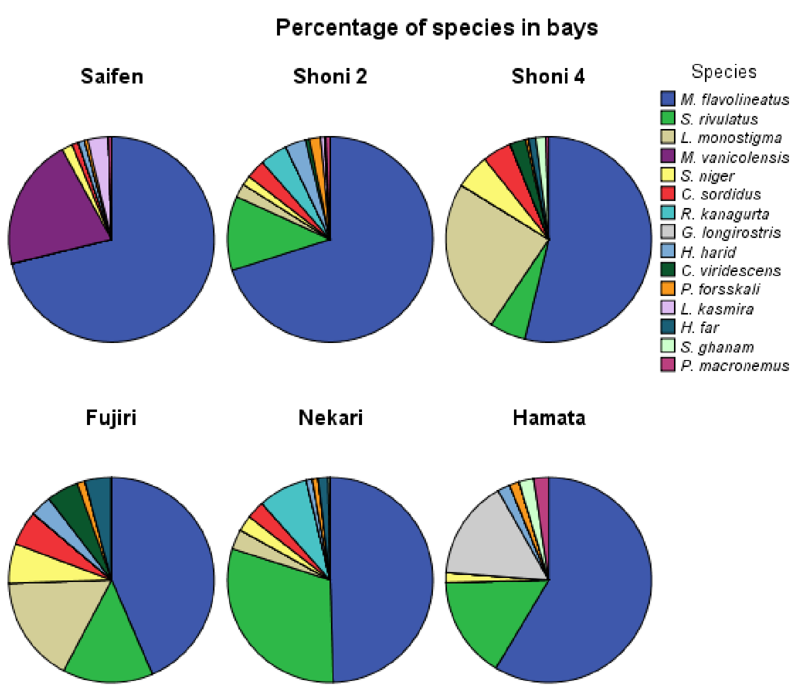

Fig. 6. Percentage contribution of the most abundant species in different bays.

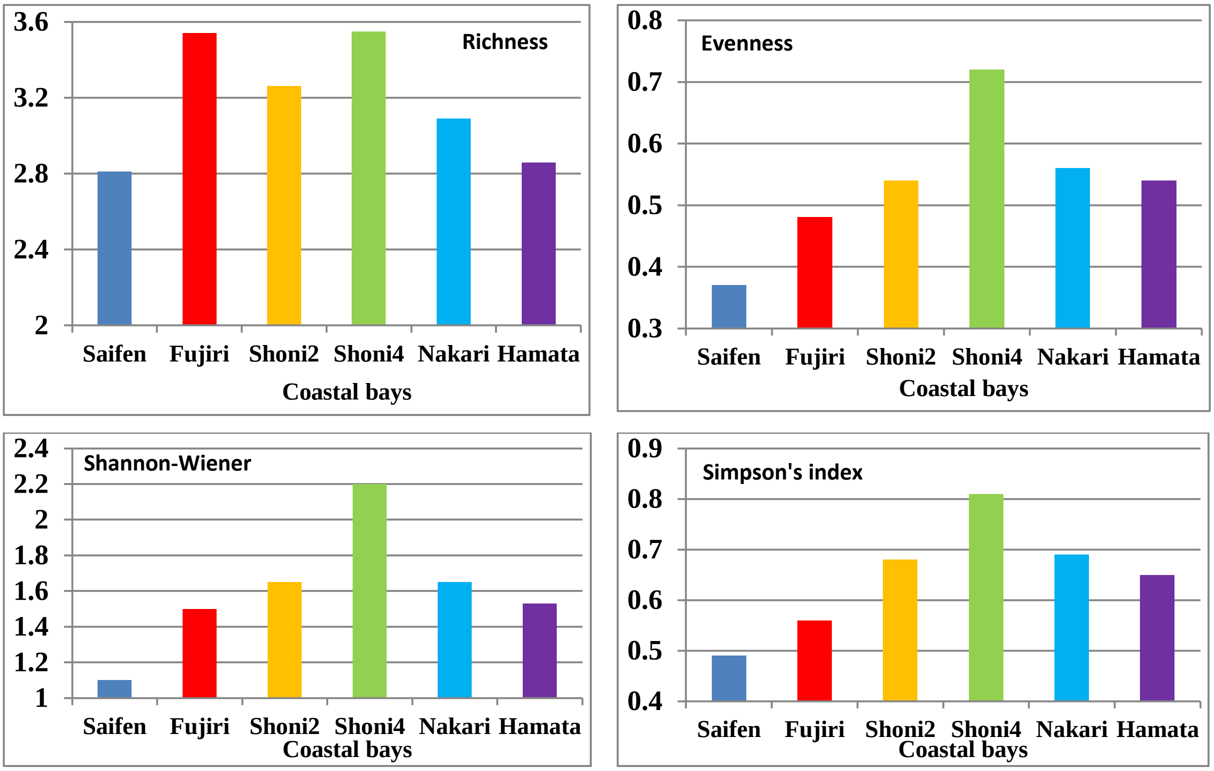

Fig. 7. Diversity and abundance indices for different coastal bays of Marsa Alam.

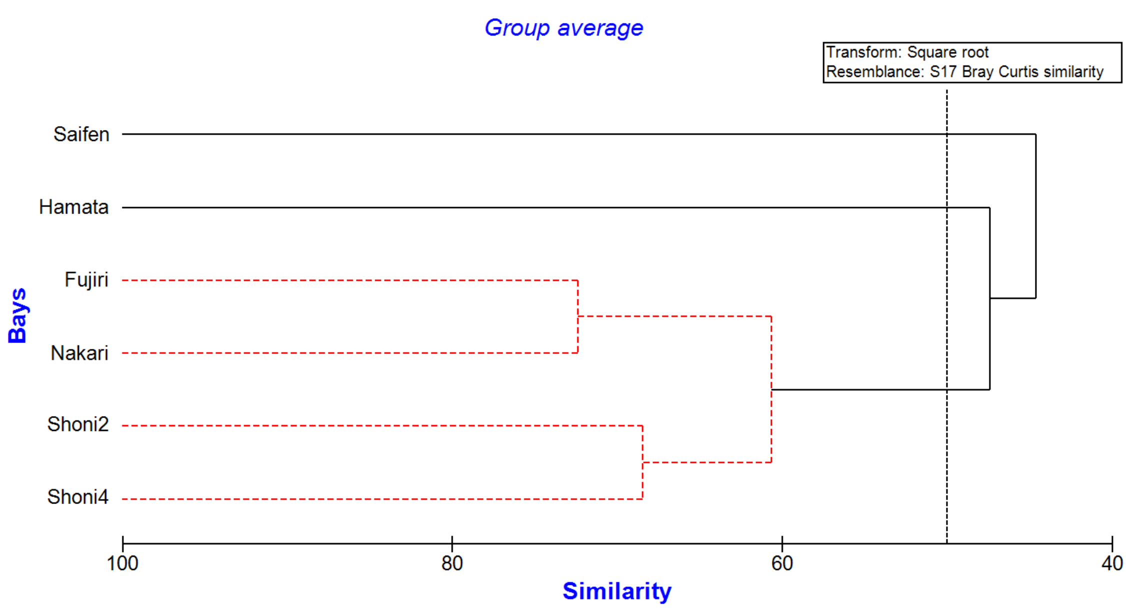

Fig. 8. Bray–Curtis similarity cluster between bays along Marsa Alam coast, Red Sea.

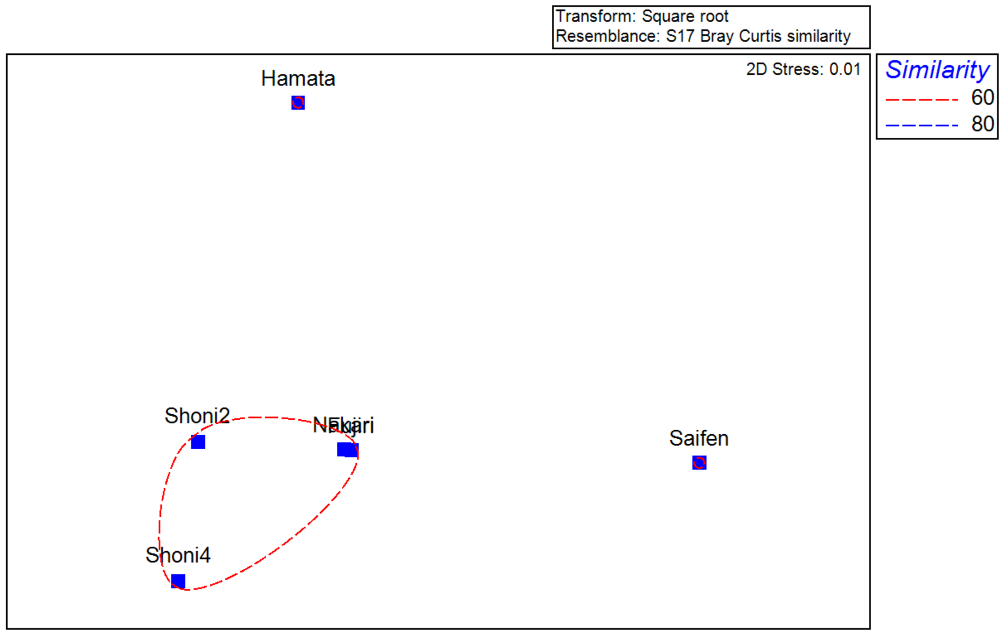

Fig. 9. Euclidean Distance Non-Metric Multi-Dimensional Scaling of bays along Marsa Alam coast, Red Sea.

4. Discussion

The present visual censuses recorded 44 commercial reef fish species belonging to 16 families. The family Scaridae was the most diverse family and it comprised 8 species followed by Serranidae and Mullidae which included 6 and 5 species, respectively. Each of Lutjanidae and Letherinidae had 4 species. On the other hand, 6 fish families (Hemiramphidae, Nemipteridae, Kyphosidae, Priacanthidae, Scombridae and Platycephallidae) were represented by only one species.

However, Shellem *et al*. (2021), in their study on the coral reef fish market diversity and abundance in the central Red Sea of Saudi Arabian water, that a high proportion of the market composition is generated by 46 species from six family-level groups, Serranidae, Lethrinidae, Scaridae, Labridae, Carangidae and Lutjanidae. They recorded that the family Serranidae was the most diverse family, followed by Lethrinidae and Scaridae.

Abu El-Regal (2014) recorded 4388 fish constituting 94 species in 23 families of coral reef fish in Wadi El-Gemal protected area and Maaty *et al*. (2021) recorded 93 reef fish species, belonging to 26 families along the northern Egyptian Red Sea coast in Hurghada and Safaga. Abundance and diversity of reef fish recorded by Abu El-Regal (2014) and Maaty *et al*. (2021) seems comparable to the abundance and diversity of fish recorded during the present study. The present study focuses only on the species of commercial importance and other species were excluded from the analysis. The more diverse family in this area was Labridae containing 16 species, followed by Chaetodontidae and Scaridae with 10 and 9 species, respectively, then Acanthuridae and Pomacentridae with 7 species for each, and Holocentridae, Mullidae and Serranidae were represented by 5 species for each. In this respect, many authors concluded that the diversity of coral reef fish families in the Red Sea was varied according to the distribution of these fishes in different areas of the Red Sea due to the local and global human impacts

(Roberts & Ormond, 1987; Roberts *et al*., 1992; Pandolfi *et al*., 2003; Bellwood *et al*., 2004).

The present study recorded that four families (Mullidae, Siganidae, Scaridae and Lutjanidae) were the most abundant and they formed about 91.3% of the total number of recorded individuals. The most abundant family was Mullidae (contained 63.5% of the total number of individuals). These results were in agreement with that recorded by Maaty *et al*. (2021) in waters along the northern Egyptian Red Sea coast; where they showed that, from the recorded 93 reef fish species, only 10 species belonging to 6 families (Acanthuridae, Mullidae, Labridae, Siganidae, Atherinidae and Pomacanthidae) were the mostly abundant fishes (representing 55.6% of all recorded fish individuals) in the coral reef of their studied areas.

The current study showed that the highest number of species (23 species) were observed in Marsa Fujiri represented about 52.3% of the total collected fish species, whereas the lowest number of species was recorded in Hamata (17 species) representing about 38.6% of the total collected fish species. While the highest abundance of fish was recorded in Marsa Saifen (609 individuals) and the lowest abundance was recorded at Hamata (271 individuals). These results indicated that diversity and abundance were decreased from north to south bays. In the same way, Maaty *et al*. (2021) found that the highest diversity (54 species) was recorded in north Hurghada, while the lowest (18 species) was detected in middle Hurghada; the highest fish abundance was recorded in north Hurghada with 4432 fishes, and the lowest fish abundance was found in middle Hurghada with 292 individuals.

5. Conclusion and Recommendations

Knowledge of the ecology of marine fish communities is sparse and quantitative ecological studies are needed. Action plans and research programs must be developed in order to reduce early stages bycatch and initiate fisheries management strategies for commercially exploited species.

This study filled in a major gap in records for the distributions of commercial coral reef fish species and is further evidence of the changing of biodiversity in the Red Sea, which may affect the ecosystem and the commercial fisheries. The results emphasize the need for a continuous, directed, and monitoring and management plan for the detection and abundance monitoring of the commercial species. It is not just the fish populations that need protecting but also the environment that supports them.

Furthermore, a map of the spawning and nursery grounds for all fishes in the area should be prepared on the basis of sound biological research. Thus, the protection of juveniles is probably the key factor for the sustainability of the resource, through periodic spatial closure of the spawning and nursery areas. This may be achieved through the establishment of certain reserves to protect the spawning stock biomass, and then monitoring their effects as a management strategy. Moreover, the link between spawning and recruitment in the area should be established.

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تنوع ووفرة الأسماك التجارية في بعض الخلجان المرجانية الساحلية بمرسى علم، البحر الأحمر، مصر

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المستخلص. يهدف هذا العمل إلى دراسة تنوع ووفرة مجتمعات الأسماك التجارية الشائعة في ستة خلجان للشعاب المرجانية الساحلية، حول مدينة مرسى علم، على الساحل الجنوبي للبحر الأحمر المصري. تم إحصاء المجتمعات السمكية في ستة مواقع، مرسى سيفين، مرسى شوني ٢، مرسى شوني ٤، مرسى فوجيري، مرسى نكاري، ومرسى حماطة، باستخدام تقنية التعداد البصري تحت الماء (UVC). وتم التعرف على إجمالي ٢٤٥٨ سمكة تنتمي إلى ١٦ عائلة و٤٤ نوعًا من الأسماك التجارية. خمس فصائل (Scaridae، وSerranidae، وMullidae، وLutjanidae، وLethrinidae) تحتوي على ٢٧ نوعًا (٦١,٤٪ من إجمالي عدد الأنواع). كانت أربع فصائل (Mullidae، وSiganidae، وScaridae، وLutjanidae) هي الأكثر وفرة، وشكلت حوالي ٩١,٣٪ من إجمالي عدد الأفراد المسجلين. كانت Mullidae هي الأكثر وفرة، حيث شكلت حوالي ٦٣,٥٪ من مجتمع الأسماك. وكانت الأنواع الأكثر وفرة هي *Mulloidichthys flavolineatus*، من عائلة Mullidae مع ١٣٩٠ فردًا تشكل ٥٦,٥٪، يليها *Siganus rivulatus* من عائلة Siganidae (٢٥١، ١٠,٢٪). بينما سُجلت أعلى وفرة للأسماك في مرسى سيفين (٦٠٩ فردًا) وأقل وفرة سجلت في حماطة (٢٧١ فردا). وقد لوحظ أكبر عدد من الأنواع (٢٣ نوعًا) في مرسى فوجيري، في حين أن أقل عدد من الأنواع (١٧ نوعا) تم تسجيله في حماطة. إن المعرفة ببيئة المجتمعات السمكية البحرية في البحر الأحمر قليلة. ومن هنا، فإن هناك حاجة إلى دراسات بيئية للمعرفة الكمية، ويجب وضع خطط عمل وبرامج بحثية للحد من الصيد العرضي في المراحل المبكرة، وبدء استراتيجيات إدارة مصايد الأسماك للأنواع المستغلة تجاريًا.

الكلمات المفتاحية: أسماك الشعاب المرجانية التجارية، الخلجان، البحر الأحمر.

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Age and Growth of the Silver Grunt *Pomadasys argenteus* (Forsskal, 1775) in Jizan Fisheries, Saudi Arabia

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Abstract. The silver grunt *Pomadasys argenteus* is one of the commercial fish species in the family Haemulidae widely distributed in the Indo-West Pacific (from Red Sea to Fiji). The age of this species was determined using scales. The back-calculated lengths-at-ages were estimated using the body proportional hypothesis (BPH) based on the relation between the body length and scale measurements. The relationship between the scale radius (S) and total length (L) could be described by the linear form: L = 4.632 S - 4.813 (R^2 = 0.93) for males, L = 4.37 S - 2.761 (R^2 = 0.94) for females, and L = 4.39 S - 3.28 (R^2 = 0.95) for pooled sexes. Seven age groups were determined for females (I^+ to VII^+), and five groups for males (I^+ to V^+). Growth parameters were estimated from the growth rates and found to be L_∞ (asymptotic length) = 52.33 cm, K (growth coefficient) = 0.197 yr^{-1}, and t_o (supposed age at zero length) = -0.74 yr for males; L_∞ = 57.39 cm, K = 0.174 yr^{-1}, and t_o = -0.82 yr for females; and L_∞ = 56.07 cm, K = 0.181 yr^{-1}, and t_o = -0.79 yr for pooled sexes. The length-weight relationship was described by the nonlinear power equation: W = 0.0130 $L^{3.014}$ (R^2 = 0.99) for males, W = 0.0146 $L^{2.98}$ (R^2 = 0.99) for females, and W = 0.0138 $L^{3.00}$ (R^2 = 0.99) for pooled sexes. The growth of this species is isometric where the regression slope for both sexes does not differ significantly from the value ' 3 ' of the isometric growth. The life span (maximum age) was estimated to be 16.4 yr for females, 14.5 yr for males, and 15.8 yr for combined sexes, indicating that the silver grunt in Jizan fisheries is a moderate sized fish species (between 10 to 20 yrs).

Keywords: *Pomadasys argenteus*, age determination, Growth parameters, life span, Jizan fisheries.

1. Introduction

Fishes of the family Haemulidae are commonly known as grunts due to their ability to produce sound by grinding their teeth. This family has 136 species in 19 genera (Fricke *et al.*, 2021). These fishes are found in tropical marine, brackish and rarely fresh waters in the Indo-West Pacific region (from Red Sea to Fiji). They are found mainly in inshore waters, particularly in mangroves and soft-bottom habitats, feeding mainly on benthic invertebrates such as bivalves, shrimps and polychaetes (Sheaves and Molony, 2000, Kulbicki *et al.*, 2009).

Some species of Grunts are highly priced food fishes and represent one of the major components of the fish biomass in the coastal waters in the Indo-Pacific. The silver grunt *Pomadasys argenteus* is one of the larger species of grunts, reaching 60 cm SL (McKay, 1998). It is a major food fish targeted in both commercial and recreational fishing (Ley *et al.*, 2002).

Life history parameters of fishes estimated based on age studies (Choat and Robertson, 2002) are necessary in investigating the effect of fishing on fish populations and how they respond to their exploitation (Jennings *et al.*, 2001), and in assessment of the status of fish stocks (Grandcourt, 2005). Several studies have been conducted on the growth of silver grunt from different fisheries (Brothers and Mattews, 1987; Bade, 1989; Mathews and Samuel, 1991; Salman *et al.*, 2005; Kulbicki *et al*., 2009).

In Jizan Fisheries, this species is one of the important food fish caught mainly in the commercial trawl and artisanal gillnet fishing. However, little is known about the growth and biology of this species in the Red Sea. The aim of the present study is to determine age and growth parameters of the silver grunt *P. argenteus* in Jizan fisheries.

2. Materials and Methods

Monthly samples of the silver grunt *Pomadasys argenteus* (a total of 338 specimens) from Jizan fisheries were collected randomly during the period from September 2019 to March 2020 from the fish landing site of Jeddah, where most of the trawl catch is being marketed at early morning. The total fish length was measured to the nearest 0.1 cm and total body weight to the nearest 0.1 g. To describe the length-weight relationship, the following power equation was used:

$$W = a L^b \qquad \text{(Le Cren, 1951)}$$

The constants a and b were estimated by the linear regression analysis between the Ln L (independent variable) and Ln W (the dependent variable) through the linear form:

$$\ln W = \ln a + b \ln L$$

To determine if the growth is isometric or not, the Pauly's t-test (Pauly, 1984) was used to test if the slope b is different from the value ' 3 ' of the cubic law.

For age determination, scales were removed and cleaned in water, dried and mounted between two microscope glass slides. The scales were examined under a stereo-zoom microscope (AmScope) using a digital video camera (AmScape18 MP) connected to a computer. The pictures of scales were saved for later measurements.

The relationship between the body length (L) and scale radius (S) was described using the linear regression of total length (L) on the scale radius (S) according to the linear form:

$$L = c + d S$$

Where 'c' is the intercept, and 'd' is the slope. The back-calculated lengths-at-ages were estimated using Body proportional hypothesis (BPH) as described in Francis (1990):

$$L_i = [(c + dS_i) / (c + dS)]\, L$$

Where, L_i is the back-calculated length at the time of annulus ' i ' formation, S_i is the radius of the annulus ' i '. The average calculated lengths at ages were estimated and the annual rates of growth in length and in weight were determined. The growth parameters of von Bertalanffy (1938) growth equation (VBGE):

$$L_t = L_\infty \left[1 - e^{-K(t - t_0)}\right]$$

The asymptotic length (L_∞) and the growth coefficient (K) were estimated using Ford (1933) and Walford (1946) method, by fitting the method to the average back-calculated lengths-at-ages for males, females and sexes combined. The hypothetical age at zero length (t_0) was estimated using the following empirical equation suggested by Pauly (1980):

$$\log(-t_0) = -0.3922 - 0.2752 \log L_\infty - 1.038 \log K$$

The formula suggested by Pauly and Munro (1984): $\Phi' = \log K + 2 \log L_\infty$ was used to estimate the growth in length performance index (phi-prime, Φ') for this species in Jizan fisheries. The maximum life span of *P.*

argenteus in Jizan fisheries was estimated using the following form suggested by Taylor (1958):

$$t_{max} = t_0 + 3 / K$$

3. Results and Discussion

3.1 Age Determination

Depending upon the characteristic pattern recognized on the scales (Fig. 1), and the annual time scale (Williams and Bedford, 1974) assigned for each annulus (annual check mark), the scales of *P. argenteus* were used for age determination. The time scale assigned for the annual check marks has been confirmed in previous studies on this species used scales (Bade, 1989), and otolith (Salman *et al*., 2005, Kulbicki *et al*., 2009) for age determination. The number of annuli formed on the scales was counted and the age (in years) could be assigned to each specimen. Seven age groups (I^+ - VII^+) and 5 age groups (I^+ - $V^{+)}$ were determined for females and males, respectively.

3.2 Body Proportional Hypothesis (BPH)

Figure 2 shows the relationship between the total fish length and scale radius for pooled data. This relationship was found to be linear based on the following equation:

For males, $L = 4.63\ S - 4.81$ ($R^2 = 0.93$)

For females, $L = 4.37\ S - 2.76$ ($R^2 = 0.94$)

For sexes combined, $L = 4.39\ S - 3.28$ ($R^2 = 0.95$)

The individual back-calculated lengths-at-ages were calculated using the body proportional hypothesis (BPH) formula for sexes combined:

$$L_i = [(3.28 + 4.39\ S_i) / (3.28 + 4.39\ S)] \times L$$

The average back-calculated lengths at ages estimated for males, females and sexes combined are illustrated in Table 1 and Fig. 3. The analysis of variance showed no significant difference between the average calculated lengths at ages for males and those at corresponding ages for females and sexes combined (ANOVA: F = 0.2974, *P* = 0.827). This indicates that both sexes of *P. argenteus* in Jizan fisheries have similar growth pattern that agrees with previous studies on the same species (Brothers and Mathews, 1987; Bade, 1989; Salman *et al.,* 2005; Kulbicki *et al*., 2009)

3.3 Growth in Length

As shown in Table 1 and Fig. 4, the maximum growth rate in length occurred through the first year (15.5 cm). During the second year, the growth rate decreased to 6.7 cm. The growth rates during the first and the second year of life was 22.3 cm, collectively, which is equivalent to 51% of the maximum observed length 44 cm. This conclusion agrees with the observations of Legendre and Albaret (1991) for wild fish populations. The growth in length displayed gradual decrease during the next years, reaching the minimum in the 7^{th} year of age (2.2 cm).

However, similar results were recorded in previous research on this species at different localities. Based on the otolith microstructures of *P. argenteus* in the Persian Gulf, Brothers and Mathews (1987) estimated the length at the fifth year of life to be 358 mm total length which is also very close to our calculated length of 364 mm total length at the end of fifth year. Bade (1989) used scales for age determination of *P. argenteus* in North Queensland waters and reported that the largest fish sampled was 430 mm total length and from the marks observed on the scales he suggested that its age was between 5 and 6 years old. Also, Salman *et al*. (2005) used otoliths for age determination of *P. argenteus* in Red Sea fisheries of Yemen (very close to Jizan Fisheries) and recorded six age groups for fish ranging in total length from 130 to 440 mm. Similarly, Kulbicki *et al.* (2009) used fish otoliths for age determination and reported similar growth pattern for *P. argenteus* in New Caledonia, where fish can attain 341 mm (Fork length) by the end of fifth year of life which is very close to our findings (if the fork length converted to total length).

3.4 Growth Parameters and Performance Index

The von bertalanffy growth curve for *P. argenteus* (for sexes combined) in Jizan fisheries is shown in Fig. 5. Listed in Table 2 are the results obtained compared to the results estimated for the same species by different authors at different localities.

The following equation is the von Bertalanffy Growth Function (VBGF) used to estimate the growth curve of *P. argenteus* in Jizan fisheries shown in Fig. 5:

$$L_t = 56.07 \, [1- e^{-0.181 \, (t + 0.79)}]$$

Based on the results obtained for the asymptotic length and the growth coefficient, the performance index of growth in length (phi-prime, Φ') of the silver grunt in Jizan fisheries was estimated to be 2.73, 2.76 and 2.75 for males, females and pooled sexes, respectively.

However, the results in Table 2 show considerable variability among growth parameters and performance index. This might be due to using different methods and techniques to determine age and estimate back-calculated lengths at ages. For example, different sites of scales used, scales measuring at different angles and poor representation of all size groups, in addition to different geographical distribution can result in a wide variation in the parameters of the regression analyses used in the back-calculation methods (Carlander, 1982; Hirschhorn & Small, 1987; Taylor *et al.*, 2020).

3.5 Length-weight Relationship

The length-weight relationship for males, females and combined sexes of *P. argenteus* in Jizan fisheries could be described by the following equations:

For males,

$$W = 0.0130 \, L^{3.01} \quad (R^2 = 0.986, n = 155)$$

For females,

$$W = 0.0146 \, L^{2.98} \quad (R^2 = 0.987, n = 183)$$

For combined sexes,

$$W = 0.0138 \, L^{3.00} \quad (R^2 = 0.986, n = 338)$$

The observed and predicted weights for 338 specimens of *P. argenteus* (combined sexes) displayed total length range from 15.5 – 44.0 cm and total weight from 41 – 1127 gm (Fig. 6).

The Pauly's t-test, indicates isometric growth for males and females of *P. argenteus* in Jizan fisheries, where the exponent 'b' values for both sexes were not significantly different from the value '3' of the isometric growth (for males: t = 0.342, critical t = 1.96 for $P = 0.05$; for females: t = 0.576, critical t = 1.96 for $P = 0.05$). These results are comparable with other previous studies (Table 3).

The values of the exponent b during the present study (2.74 to 3.138), fall within the range (2.5 to 3.5) suggested by Carlander (1969) and reported by Froese (2006). The variability of b values may be due to different factors such as food availability and water temperature which differs among seasons and regions, in addition to sex, length type and range of the specimens used in the regression analysis (Tesch, 1971; Pitcher and Hart, 1982)

3.6 Growth in Weight

One of the benefits of the length-weight relationship in fish is converting the lengths at ages to weights at ages. So, the weights-at-ages corresponding to the length-at-ages were calculated by using this relationship described for *P. argenteus* in Jizan fisheries. Results are represented in Fig. 7 showing the growth in weight and annual increment. The maximum growth in weight was attained during the sixth year of life (221.6 gm). The maximum asymptotic weight corresponding to the asymptotic length (L_∞ = 56.07 cm) was estimated to be 2403 gm.

3.7 Maximum Age (Life span)

Taylor (1958) suggested the following form to estimate the maximum life span of fish:

$$t_{max} = t_0 + 3 / K$$

Where, t_{max} is the maximum life span (longevity) of fish having a length equal to 95% of the maximum asymptotic length L_∞. K and t_0 are the estimated growth parameters. This form was used to estimate the longevity of *P. argenteus* in Jizan fisheries. Females were found to have longer life span (16.4 yr) than males (14.5 yr), and the longevity for pooled sexes was estimated to be 15.8 yr. It has been supposed that fish having a life span of more than 20 years are long-lived species (King and McFarlane, 2003; Martinez-Andrade, 2003; Newman *et al*., 2016). Accordingly, *P. argenteus* in Jizan fisheries is a moderate sized fish having a maximum life span lower than 20 yrs. In North Queensland, this species was reported as a moderate sized fish attaining the maximum asymptotic length (481 mm) in approximately 10 years (Bade, 1989).

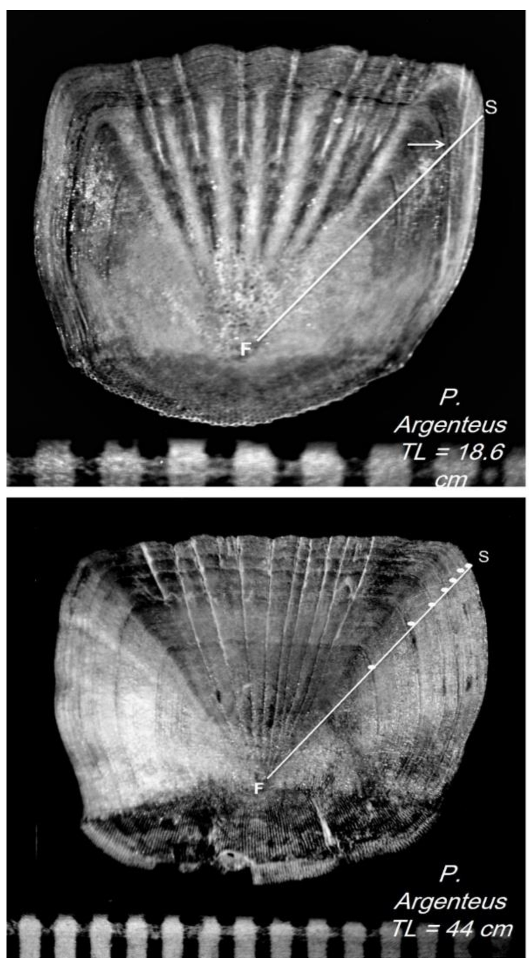

Fig. 1. A scale of 18.6 cm (top: age group I+) and 44 cm (bottom: age group VII+) total length specimens of *P. argenteus* in Jizan fisheries showing the annual check marks (F is the focus, and S is the scale radius).

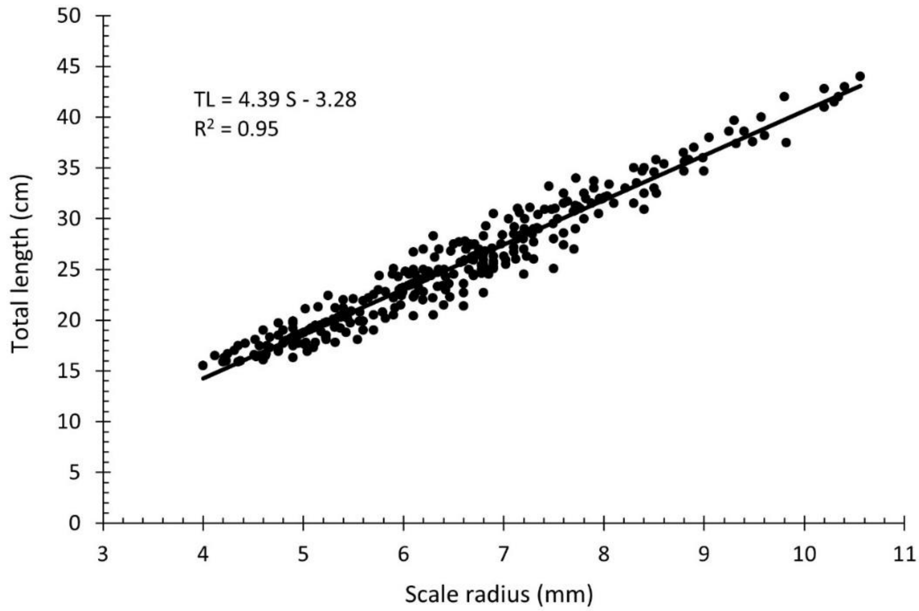

Fig. 2. Total length–Scale radius relationship of *P. argenteus* (combined sexes) in Jizan fisheries.

Table 1. The average back-calculated lengths at ages for males, females and sexes combined of *P. argenteus* in Jizan fisheries.

Age	Average back-calculated length			Annual increment (pooled)	VBGF (pooled)
	Males	Females	Combined sexes		
1	15.6	15.7	15.5	15.5	15.5
2	22.1	22.3	22.2	6.70	22.2
3	27.6	2 7.8	27.6	5.40	27.8
4	32.0	32.6	32.4	4.80	32.5
5	35.6	37.0	36.4	4.00	36.4
6		40.1	40.1	3.70	39.7
7		42.7	42.3	2.20	42.4

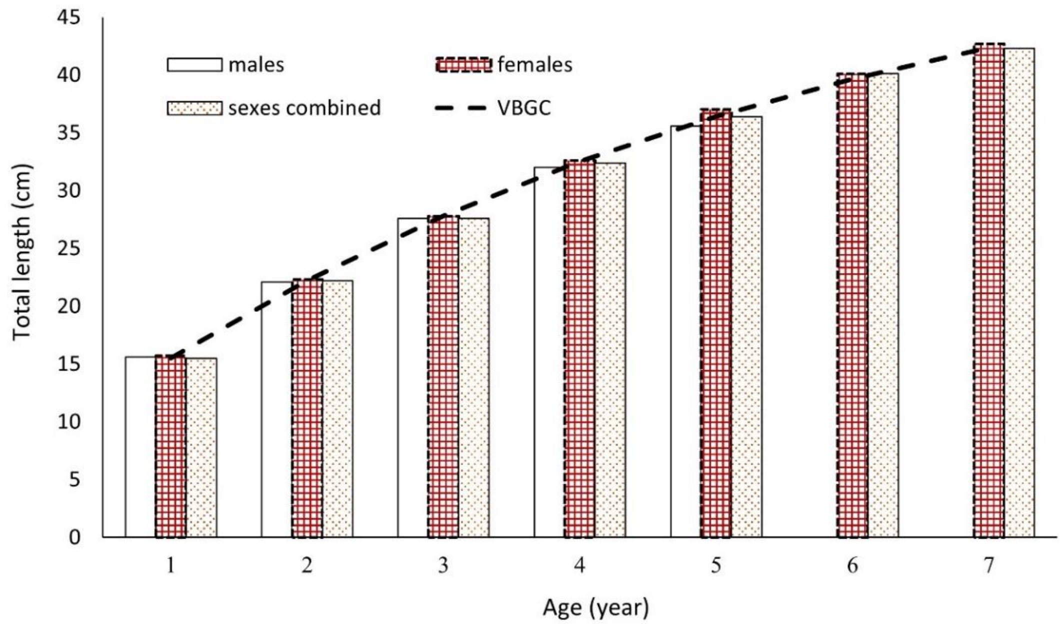

Fig. 3. The mean back-calculated lengths at ages estimated by body proportional hypothesis (BPH) for males, females and sexes combined of *P. argenteus* in Jizan fisheries.

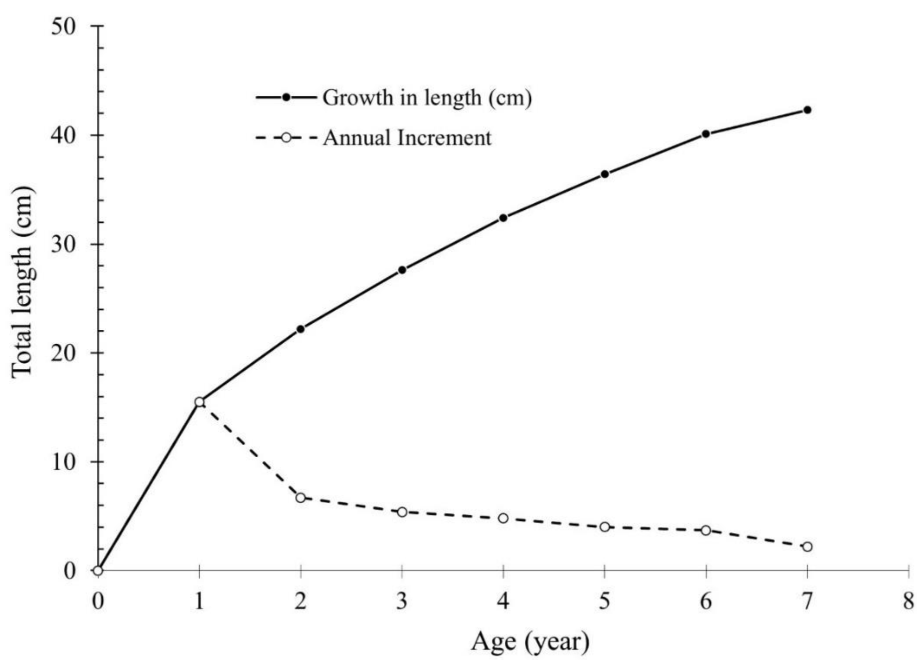

Fig. 4. Growth in length and annual increment of *P. argenteus* in Jizan fisheries.

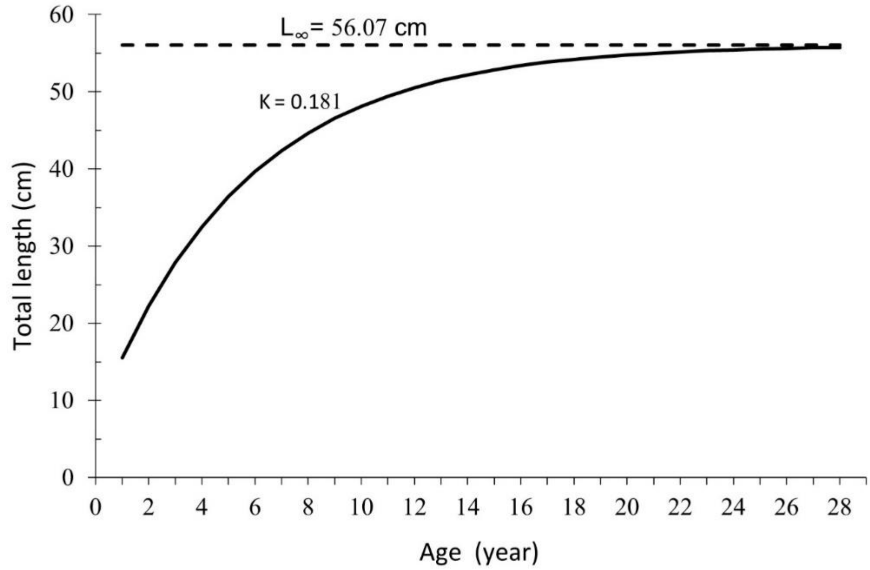

Fig. 5. von Bertalanffy growth curve for *P. argenteus* (sexes combined) in Jizan fisheries.

Table 2. Growth parameters and Growth performance index (Φ') of *P. argenteus* at different locations estimated by different authors.

Author (Locality)	Method	Sex	L_∞ (cm)	K (yr^{-1})	t_0 (yr)	Φ'
The present study (Red Sea- Jizan)	Scales TL	M	52.33	0.197	-0.738	2.73
		F	57.39	0.174	-0.816	2.76
		C	56.07	0.181	-0.791	2.75
Kulbicki *et al*. (2009) (New Caledonia)	Otoliths FL	C	42.00	0.346	0.161	2.79*
Mathews and Samuel (1990) (Kuwait)	Otoliths TL	C	67	0.238	NA	3.03
Bade (1989) (North Queenland)	Scales TL	C	48.1	0.384	0.012	2.95*
Brothers and Mathews (1987) (Iran)	Otoliths TL	C	55.1	0.210	NA	2.80

M is Male, F is Female, C is Combined sexes, TL is the Total Length, FL is the Fork Length
* Estimated from K and L∞ values.

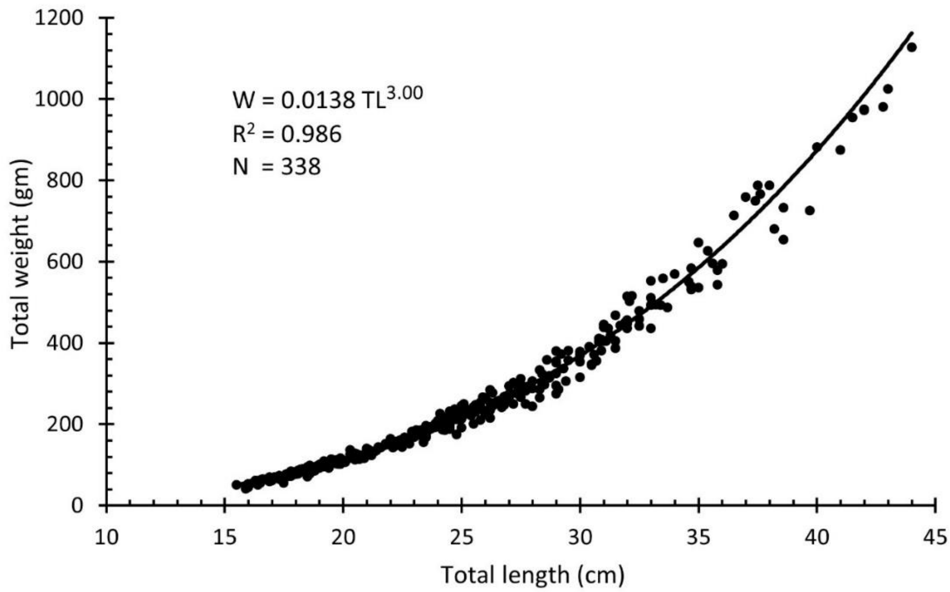

Fig. 6. Length-weight relationship of *P. argenteus* (sexes combined) in Jizan fisheries.

Table 3. Length-weight relationship parameters of *P. argenteus* estimated by different Authors at different localities.

Authors	Sex	a	b	R^2	N	Size range (cm)
The present study (Red Sea, Jizan)	M	0.0130	3.01	0.986	155	15.5 – 36.0 TL
	F	0.0146	2.98	0.987	183	15.9 – 44.0 TL
	C	0.0138	3.00	0.986	338	15.5 – 44.0 TL
Karna *et al*. (2020) (Chilika Lagoon, India)	C	0.0140	3.01	0.984	23	5.0 – 16.2 TL
Kulbicki *et al*. (2009) (New Caledonia)	C	0.0229	2.937	0.994	869	14.0 – 44.0 FL
Salman *et al*. (2005) (Red Sea, Yemen)	C	0.032	2.74	NA	166	13.9 – 44.2 TL
Al Sakaff and Esseen, (1999) (Yemen)	M	0.0090	3.138	0.891	214	13.5 – 39.2 TL
	F	0.0150	2.999	0.873	200	14.5 – 38.4 TL

M is Male, F is Female, C is combined sexes, TL is the Total Length, FL is the Fork Length

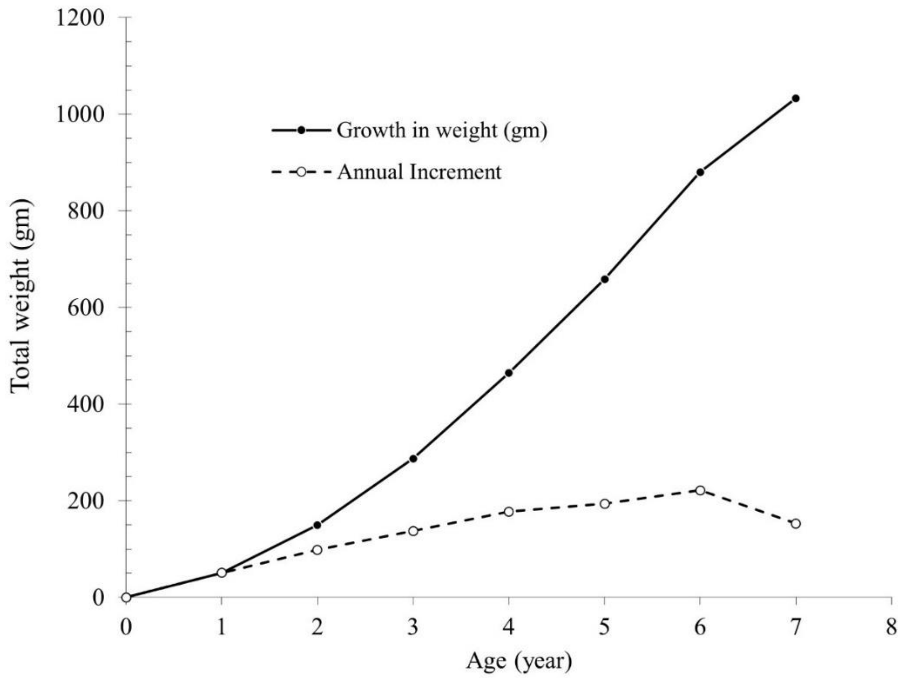

Fig. 7. Growth in weight and annual increment of *P. argenteus* (sexes combined) in Jizan fisheries.

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تحديد العمر والنمو لأسماك الناقم (*Pomadasys argenteus*) في مصايد جيزان – المملكة العربية السعودية

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المستخلص. أسماك الناقم (*Pomadasys argenteus*) هي أحد أنواع الأسماك التجارية في عائلة (Haemulidae) المنتشرة على نطاق واسع في المحيط الهندي وغرب المحيط الهادئ (من البحر الأحمر إلى فيجي). تم استخدام القشور فى تحديد الأعمار لهذا النوع. كما تم احتساب الأطوال المقابلة للأعمار باستخدام العلاقة التناسبية للجسم (BPH) اعتمادًا على العلاقة بين طول الجسم وقياسات القشرة. وقد أمكن وصف العلاقة بين نصف قطر القشرة (S) والطول الكلي (L) بالمعادلة الخطية: L = ٤,٦٣٢ S –٤,٨١٣ (R^2 = ٠,٩٣) للذكور، وL = S ٤,٣٧– ٢,٧٦١ (R^2 = ٠,٩٤) للإناث، وL = ٤,٣٩ S –٣,٢٨ (R^2 = ٠,٩٥) للجنسين معا. وأمكن تحديد سبع فئات عمرية للإناث (I^+ إلى VII^+)، وخمس فئات عمرية للذكور (I^+ إلى V^+). وتم حساب معاملات النمو من معدلات النمو وتبين أنها L_∞ (أقصى طول) = ٥٢,٣٣ سم، وK (معامل النمو) = ٠,١٩٧ في السنة، وt_o (العمر المفترض عند طول صفر) = –٠,٧٤ سنة للذكور؛ L_∞ = ٥٧,٣٩ سم، K = ٠,١٧٤ في السنة، وt_o = –٠,٨٢ سنة للإناث؛ وL_∞= ٥٦,٠٧ سم، K = ٠,١٨١ فى السنة، وt_o = –٠,٧٩ سنة للجنسين معا. وأمكن وصف علاقة الطول بالوزن بواسطة معادلة الطاقة غير الخطية: W = ٠,٠١٣٠ $L^{3.014}$ (R^2 = ٠,٩٩) للذكور، W = ٠,٠١٤٦ $L^{2.98}$ (R^2 = ٠,٩٩) للإناث، وW = ٠,٠١٣٨ $L^{3.00}$ (R^2 = ٠,٩٩) للجنسين معًا. ويعتبر نمو هذا النوع مثاليًا، إذ إن معامل الانحدار لكل من الذكور والإناث لا يختلف اختلافا معنويا عن قيمة '٣' للنمو المثالي. وقدر أقصى عمر (مدى الحياة) بـ ١٦,٤ سنة للإناث، و١٤,٥ سنة للذكور، و١٥,٨ سنة للجنسين معًا، مما يشير إلى أن أسماك الناقم في مصايد جيزان هو من الأنواع متوسطة الحجم.

الكلمات المفتاحية: أسماك الناقم، تحديد العمر، معايير النمو، مدى الحياة، مصايد جيزان.

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Stock Study of Bali Sardinella Fisheries at Pengambengan Nusantara Fishing Port, Bali

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Abstract. Stock assessment is one of the efforts to see the impact and influence of fishing activities on fish stocks and populations. One of the fishery resources that has important economic value in Indonesia is Bali sardinella fisheries. The high production of Bali sardinella fisheries at the Pengambengan Nusantara Fishing Port (NFP) encourages an increase in intensity and catch effort, so it is feared that overexploitation may occur. This study uses primary data and secondary data from Pengambengan NFP, to analyze the level of effort, catch, and economic rent of Bali sardinella fisheries under MSY, MEY, and OA conditions. The result of the linear equation CPUE = -0.00008f + 3.1053, if the capture effort is increased it will reduce the CPUE value, and vice versa. The regression results of the Schaefer Model obtained EMSY results of 4,691 trips per year, MSY of 17,639 tons per year, and TAC of 14,111 tons per year. The results of the bioeconomic model prediction obtained EMEY and MEY values, namely 4,554 trips per year and 17,624 tons per year.

Keywords: Sardinella lemuru, MSY, MEY, OA, Indonesia.

1. Introduction

Stock is a group of organisms of a species that have the same characteristics and occupy a certain geographical area. A stock is a group of fish whose distribution at geographical boundaries can be determined or known. Likewise with fishery activities, fishing fleets that exploit groups of fish can be known. Stock must belong to the same race within the same species. A group or subgroup of fish of a species is said to be a stock if differences in the group or mixing with other groups can be ignored without making erroneous conclusions (Saputra, 2009). Stock assessment is needed as basic information in sustainable fisheries management (Setiyowati, 2016). Sustainable and sustainable fisheries can be achieved through good fisheries resource management efforts.

Stock study is one of the efforts to see the impact and influence of fishing activities on the stock and population of these fish. Some of the benefits and uses of stock studies include guessing decision-making from management options given due to uncertainty caused by incomplete data that leads to bias, changes in technology, fishing fleets, and fish behavior including interactions between the two (Sparre and Venema, 1992). This means that stock review is the first step that will determine the next management step, so information related to identifying '*unit stock*' of fish resources is needed.

One of the fishery resources that has important economic value in Indonesia is Bali sardinella fisheries. Bali sardinella (*Sardinella lemuru*) are pelagic fish that live in shallow sea waters, flocks or *schooling*, and include surface species. The habitat of coastal waters is suitable for Bali sardinella. The highest population of Bali sardinella fish in Indonesia is in the Bali Strait to East Nusa Tenggara (Putra *et al.*, 2020). Pengambengan Nusantara Fishing Port (NFP) located in Jembrana Regency, Bali is one of the landing places for Bali sardinella originating from the waters of the Bali Strait.

The production of Bali sardinella fisheries at Pengambengan NFP itself is very high. This has led to an increase in arrest efforts made without regard to the precautionary principle which has an impact on the sustainability or sustainability of these resources (Perdana, 2012). Increasing the intensity and catch efforts of Bali sardinella fisheries in the Bali Strait, especially at Pengambengan NFP, it is feared that they will experience more exploitation or capture. This makes it important to conduct a study to analyze the level of effort, catch, and economic rent of Bali sardinella fisheries in MSY, MEY, and OA conditions and analyze the optimal utilization rate of Bali sardinella fisheries. This is related to the study of Bali sardinella resource stocks in the waters of the Bali Strait, especially those landed at Pengambengan NFP.

2. Methods

2.1 Data Collection

The research was conducted in December 2022 - May 2023 at Pengambengan NFP (Fig. 1). Primary data were obtained from observations and direct interviews with fishermen, the information asked in the form of average costs for one fishing and the average selling price of caught fish. The secondary data required in this study is time series data from catches for the last 7 years obtained from Pengambengan NFP. This study used a quantitative approach to determine the value of Maximum Sustainable Yield (MSY), Maximum Economic Yield (MEY), and Open Access (OA) in Bali sardinella.

2.2 Data Analysis

The surplus production model is an important quantitative tool for estimating equilibrium points (Worm *et al.,* 2009; Hutchings *et al.,* 2010; Branch *et al.,* 2011). The surplus production model provides a more objective assessment of stock status than methods that are only on catch (Branch *et al.*, 2011). Compared to complex scoring models, these models require only a small number of available parameters and data. Periodic data on Bali sardinella production for the last 7 years (2015–2021) that have been collected are then analyzed to calculate the Catch per Unit Effort (CPUE) value (Gulland, 1983):

$$CPUE_t = \frac{catch_t}{effort_t(f_t)}$$

In Schaefer's model, the regression performed is $y = CPUE_t$; $x = effort_t\ (f_t)$, which t stands for year. The Schaefer surplus production model is a model used to predict the potential of Bali sardinella resources based on catch and fishing effort (Kuriakose *et al.*, 2006). According to Sparre and Venema (1992) the equation of the Schaefer linear model is:

$$CPUE_t = a + b(f_t)$$

$$MSY = -\frac{a^2}{4b}$$

$$E_{MSY} = -\frac{a}{2b}$$

Furthermore, Total Allowable Catch (TAC) and the level of utilization of fish resources can be determined by analysis of surplus production based on the precautionary principle (FAO 1995 in Syamsiyah 2010), so that:

$$TAC = \frac{80\ \%}{100\ \%} \times MSY$$

Where: MSY: Maximum Sustainable Yield (tons); E_{MSY}: Optimal capture effort (trip); TAC: Total Allowable Catch (tons).

2.3 Bioeconomic Analysis

The bioeconomic analysis used is the Gordon-Schaefer model, Gordon includes economic studies of the Schaefer model. This is to explain the relationship between fish resources by including the price per unit catch and cost per unit effort factors in the function equation, to describe biological-economic interactions. There are three equilibrium conditions in the Gordon-Schaefer model, those are Maximum Sustainable Yield (MSY), Maximum Economic Yield (MEY), and Open Access (OA). Static bioeconomic analysis based on the Gordon-Schaefer model can be performed by linear regression method with the following equation:

$$y = CPUE_t$$

$$x = effort_t(f_t)$$

$$CPUE_t = a - b(f_t)$$

Where: a: intercept; b: slope.

Table 1. Bioeconomic analysis formulas of various management regimes.

Variable	Category		
	MEY	**MSY**	**OA**
Effort (E)	$\left\lvert \frac{a}{2b} - \frac{c}{2bp} \right\rvert$	$\left\lvert - \frac{a}{2b} \right\rvert$	$\left\lvert \frac{ap - c}{bp} \right\rvert$
Catch (h)	$\left\lvert Emey \left(\frac{ap + c}{2p} \right) \right\rvert$	$\left\lvert - \frac{a^2}{4b} \right\rvert$	$Eoa \left(\frac{c}{p} \right)$
Profit (π)	$p.hmey - c.Emey$	$p.hmsy - c.Emsy$	$p.hoa - c.Eoa$

Where: TR: total revenue (Rp); TC: total cost (Rp); π: profit (Rp); p: average price of fish (Rp); h: catch (tons); c: cost per unit effort (Rp); E: effort (trip).

Economic parameters that influence the bioeconomic model in capture fisheries are the cost of catching (c) and the price of catch (p). Furthermore, the calculation of the utilization rate (UR) of Bali sardinella resources uses the following formula (Wahyudi, 2010):

$$UR = \frac{Yi}{MSY} \times 100\%$$

Where: Yi: yield of year-i (tons); MSY: maximum sustainable yield (tons).

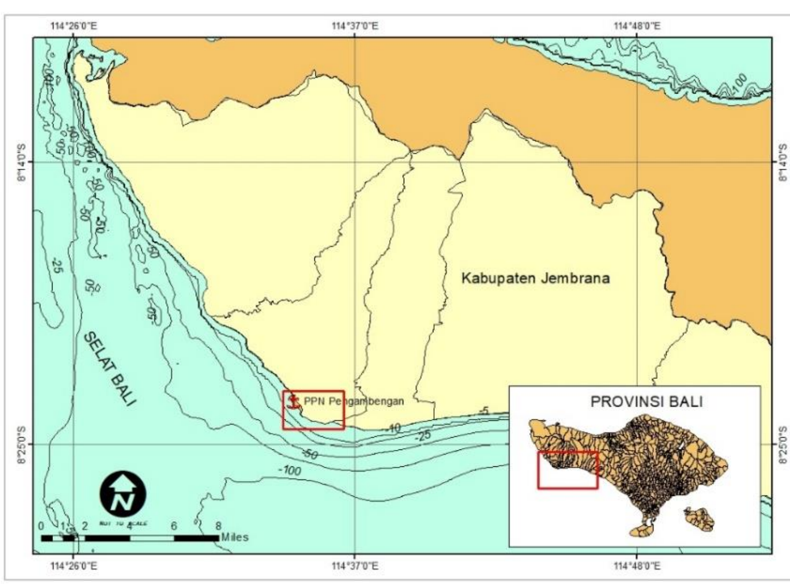

Fig. 1. Study site.

3. Results and Discussion

Based on the a and b values generated by the Schaefer Model regression, E_{MSY} results were obtained at 4,691 trips per year and MSY at 17,639 tons per year (Fig. 2). While Total Allowable Catch (TAC), which is 80% of the sustainable catch, is 14,111 tons per year.

The average utilization rate of Bali sardinella fishery resources (*Sardinella lemuru*) over the last 7 years is 59%. It is still below the point of optimal catch effort and sustainable potential (Table 2). This value is evidenced by the average catch or production for 7 years, which is 10,324 tons, lower than maximum sustainable yield (MSY). This shows that the utilization rate of Bali sardinella fishery resources at Pengambengan NFP is still sustainable. Likewise, the effort with an average of 3,794 trips is below the optimal catch effort (E_{MSY}). This status shows that the stock condition or utilization level of Bali sardinella fishery resources landed at Pengambengan NFP is still sustainable.

The year 2015 was the highest CPUE point (Fig. 3). Although CPUE dropped dramatically in 2016–2017, it increased again in 2018–2021. The decline in CPUE trends from 2016–2017 is an indicator of increased fishing efforts and a decrease in fish landing or fish production that year.

Based on Fig. 4, the relationship between effort and CPUE using the Schaefer model obtained an R^2 value of 0.0061. The intercept value (a) obtained is 3.1053 and the slope value (b) is -0.00008. The relationship between CPUE and Bali sardinella fishery catch efforts shows a negative correlation. The result of the linear equation CPUE = -0.00008f + 3.1053, shows that if the capture effort is increased, it will reduce the CPUE value, and vice versa. The value of the determinant coefficient (R^2) of the linear equation is 0.0061. The results showed that only 0.61% of the effect of the effort variable could be explained by the model, many other factors or variables not addressed in the study that affect CPUE.

Based on Fig. 5, the CPUE of Bali sardinella and scad fish experienced almost the same fluctuations and was inversely proportional to the CPUE of little tuna, fringescale sardinella and others. In general, fisheries production of Bali sardinella and other pelagic fishes was lowest in 2017. The production increased again from 2018 to 2019, then decreased until 2021.

The results also show that when Bali sardinella production is low, production is dominated by bycatch such as little tuna, scad, fringescale sardinella, and other types (Fig. 5 & 6). This result shows that several bycatch species with high selling value were also caught based on data from Pengambengan NFP.

The results of bioeconomic analysis using the Schaefer Model show that maximum profit is achieved at the point of optimal capture effort of E_{MEY} with a catch of MEY (Table 3). This indicates that E_{MEY} lower than E_{MSY} will provide maximum profit. This shows that an economic equilibrium point can be reached at the E_{MEY} point with a lower value compared to E_{MSY} so that the profits obtained are higher. In this case, an effort of 4,554 trips/year alone can generate maximum profit compared to the effort from E_{MSY} of 4,691 trips/year. In addition, bioeconomic analysis also shows that even with very high effort under EOA conditions will not produce maximum profit (Fig. 7).

The main fishing gear used to catch Bali sardinella at the Pengambengan Nusantara Fishing Port (NFP) is a small pelagic purse seine with two vessels. A small pelagic purse seine with two vessels is an active fishing gear that catches pelagic fish in groups/schooling (Wijayanto 2020; Wijayanto 2021).

Based on the Schaefer Model, the E_{MSY},

MSY, and TAC values are 4,691 trips per year; 17,639 tons per year; and 14,111 tons per year, respectively. Results of the previous study by Satyawan *et al.* (2023) obtained MSY and TAC 16,587 and 13,269 tons per year, respectively. The MSY and TAC of both studies are not much different. While study conducted by Listiani *et al.* (2016) obtained an MSY of 34,284 tons per year. The study by Listiani *et al.* used 6 years of production data (2010 – 2016) from the Pengambengan NFP and the Muncar Coastal Fishing Port (CFP), while this study used 7 years of production data (2015 – 2021) only from the Pengambengan NFP. This can affect the difference in study results obtained.

The average utilization rate of Bali sardinella Fishery resources (*Sardinella lemuru*) over the last 7 years is 59%. This value is still below the point of optimal capture effort and sustainable potential. Likewise, the effort with an average of 3,794 trips is almost close to the optimal catch effort rate (E_{MSY}). This is harmonized with previous research by Himelda *et al.*, (2011) which shows that the utilization of Bali sardinella resources for 6 years (2005-2010) is still within the permissible fishing capacity.

CPUE values in 2015 reached their highest value for the past seven years and declined dramatically in 2016–2017, then increased again in 2018–2021. The decline in CPUE trends from 2016–2017 is an indicator of increased fishing efforts and a decrease in fish landing or fish production that year. Maynou *et al.* (2003) explain that CPUE values describe species abundance and catch fluctuations. According to Weyl *et al.* (2010), CPUE variation is related to differences in the number of fishermen, working hours, and fishing gear categories. Low CPUE indicates a relatively low abundance of fish, this is related to an increase in the number of fishermen, trips, and low catches (Makwinja *et al.*, 2021).

The relationship between CPUE and Bali sardinella fishery catch efforts shows a negative correlation. A negative correlation indicates that an increase in the number of fishing efforts can lead to a decrease in productivity. However, Bali sardinella stock studies cannot be directly clinched from the comparison of production and effort, because CPUE is not a valid measure of abundance (Krisdiana *et al.*, 2013). Meanwhile, the results showed that the effort variable only described 0.61% of the CPUE value. The results of a previous study by Siegers (2016) also showed that 20.8% of effort affects the CPUE value.

The CPUE pattern of Bali sardinella landed at Pengambengan NFP over the past seven years shows fluctuations that are inversely proportional to the CPUE pattern of little tuna, fringescale sardinella, and others landed in the same location. This indicates that when the potential or production of Bali sardinella and scad is low, the production of other pelagic fish such as little tuna and fringescale sardinella is high.

The results of the bioeconomic analysis show that E_{MEY} lower than E_{MSY} will provide maximum profit. This is due to too high effort resulting in low production which has an impact on high expenditure costs, while the cost of receiving from the average price of the same fish is reduced. In Open Access (OA) conditions, profits will decrease and potentially reduce stock because the effort made has exceeded the limit of optimal capture effort or E_{MSY}. Earlier research by Siegers (2016), also stated that increasing fishing efforts can reduce the number of Bali sardinella stocks in the Bali Strait.

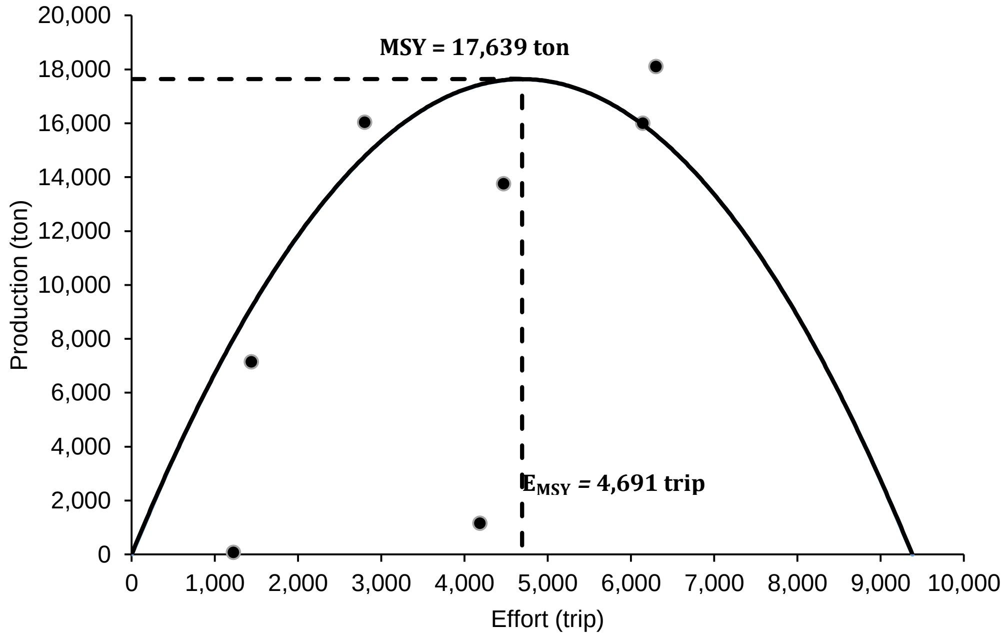

Fig. 2. **Stock equilibrium curve (MSY) of Bali sardinella (Sardinella lemuru) landed at Pengambengan NFP.**

Table 2. MSY and EMSY of Bali sardinella (Sardinella lemuru) landed at Pengambengan NFP with Schaefer linear model.

Year	Number of catches (tons)	Total standard effort	CPUE (Schaefer Model)	Utilization rates (%)
I	Yi	X	Y	UR
2015	16,038.0	2,801	5.7258	91%
2016	7,150.0	1,438	4.9722	41%
2017	76.5	1,224	0.0625	0%
2018	1,154.1	4,186	0.2757	7%
2019	16,002.9	6,141	2.6059	91%
2020	18,101.0	6,302	2.8723	103%
2021	13,747.6	4,469	3.0762	78%
Total	72,270.1	26,561	19.5906	
Average	10,324.3	3,794	2.7987	59%

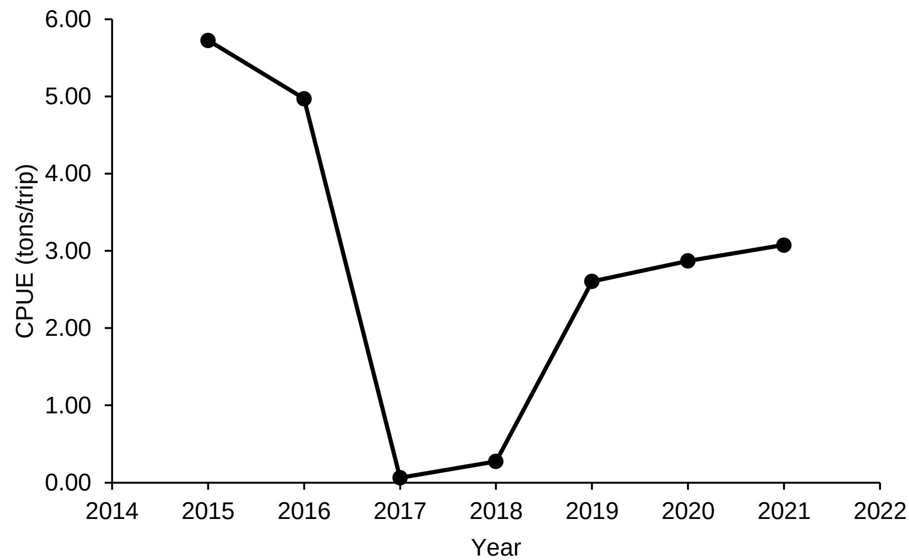

Fig. 2. CPUE fluctuation of Sardinella lemuru landed at Pengambengan NFP.

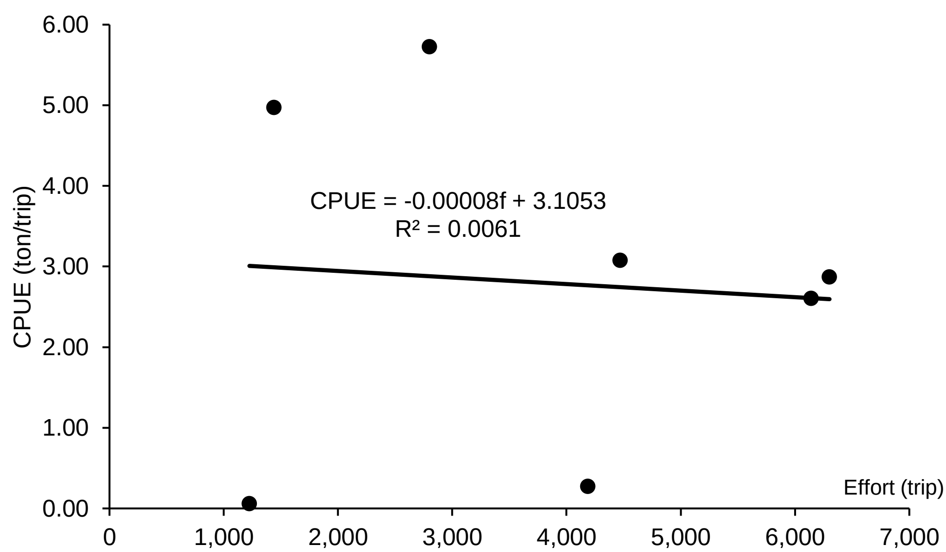

Fig. 3. Linear equations of CPUE and effort of Sardinella lemuru landed at Pengambengan NFP.

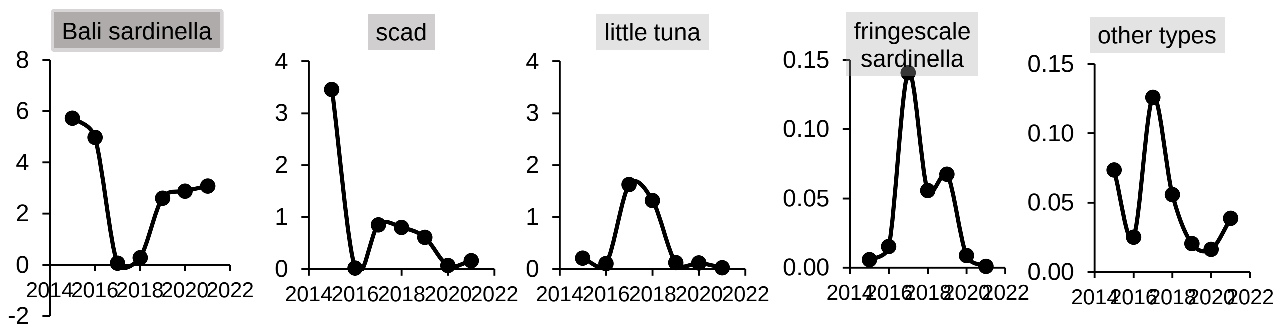

Fig. 4. CPUE pelagic fish landed at Pengambengan NFP.

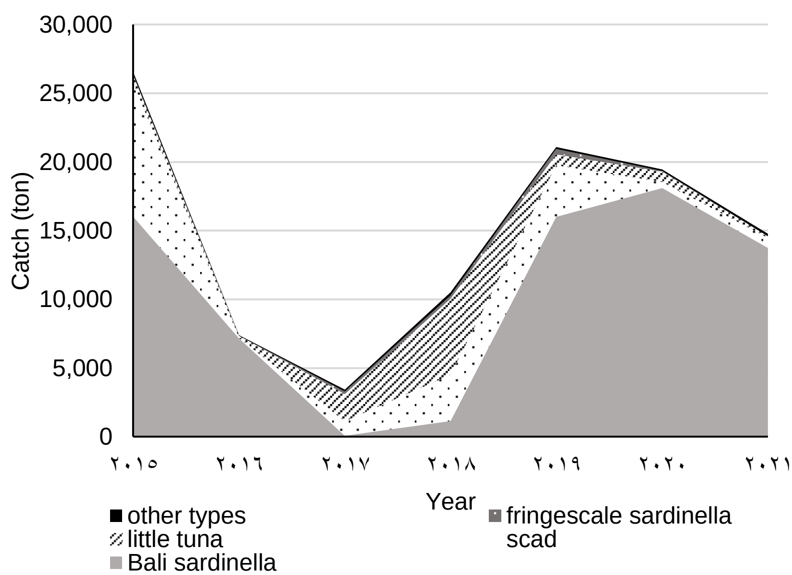

Fig. 5. Production of Bali sardinella fisheries and other pelagic fishes at Pengambengan NFP.

Table 3. Results of bioeconomic analysis of Bali sardinella resources (Sardinella lemuru) landed at NFP Pengambengan using the Schaefer Model.

Category	Catch (h)	Effort (E)	TR = p x h (Rp)	TC = c x E (Rp)	Profit (Rp)
MEY	17,624	4,554	79,942,020,349	4,553,859,332	75,388,161,017
MSY	17,639	4,691	80,010,789,883	4,691,398,400	75,319,391,483
OA	2,008	9,108	9,107,718,664	9,107,718,664	0

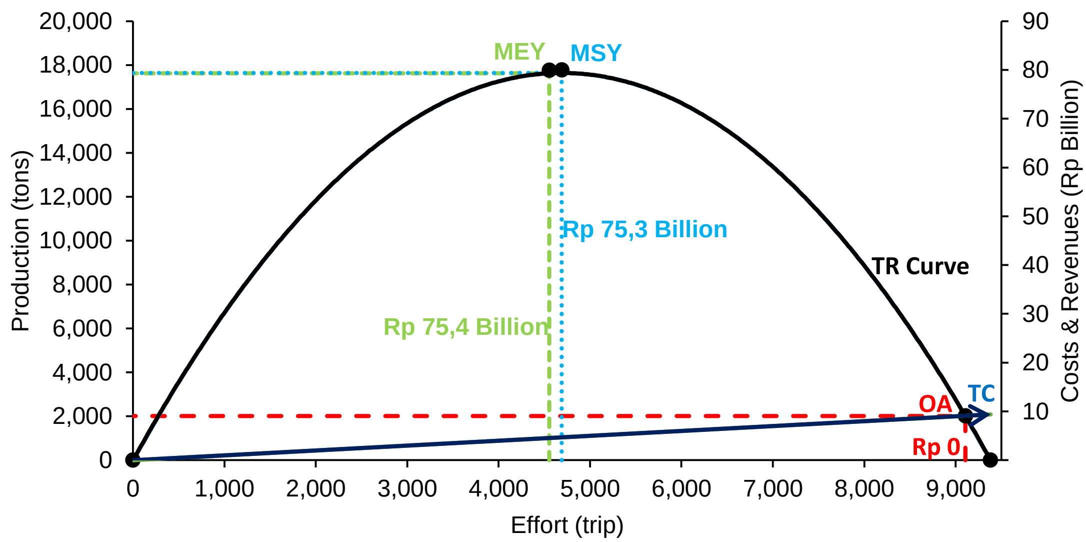

Fig. 6. Bioeconomic analysis of Bali sardinella (Sardinella lemuru) landed at Pengambengan NFP using the Schaefer Model.

4. Conclusions

The condition of Bali sardinella fishery stocks at Pengambengan NFP based on the average catch effort and the actual catch is still below the optimal balance point. Fishing efforts and actual catches of Bali sardinella fisheries by fishermen are still below E_{MEY} and MEY points based on bioeconomic predictions.

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دراسة مخزون مصايد أسماك سردينيلا في بالي بميناء صيد الأسماك بينغامبينجان نوسانتارا، بالي

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المستخلص. يعد تقييم الأرصدة أحد الجهود المبذولة لمعرفة تأثير وتأثير أنشطة الصيد على الأرصدة السمكية والسكان. إحدى الموارد السمكية التي لها قيمة اقتصادية مهمة في إندونيسيا هي مصايد أسماك السردينيلا في بالي. يشجع الإنتاج المرتفع لمصايد أسماك السردينيلا في بالي في ميناء بينغامبينجان نوسانتارا لصيد الأسماك على زيادة كثافة وجهود الصيد، لذلك يخشى حدوث استغلال مفرط. تستخدم هذه الدراسة البيانات الأولية والبيانات الثانوية من Pengambengan NFP، لتحليل مستوى الجهد والصيد والإيجار الاقتصادي لمصايد أسماك السردينيلا في بالي في ظل ظروف MSY و MEY و OA. نتيجة المعادلة الخطية CPUE = -0.00008f + 3.1053، إذا زاد جهد الالتقاط سيقلل من قيمة CPUE، والعكس صحيح. حصلت نتائج الانحدار لنموذج شيفر على نتائج EMSY لـ ٤,٦٩١ رحلة سنويًا، و MSY 17,639 طنًا سنويًا، و TAC 14,111 طنًا سنويًا. حصلت نتائج تنبؤ نموذج الاقتصاد الحيوي على قيم EMEY و MEY، وهي ٤,٥٥٤ رحلة سنويًا و ١٧,٦٢٤ طنًا سنويًا.

الكلمات المفتاحية: سردينيلا ليمورو، MSY، MEY، الزراعة العضوية، إندونيسيا.

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Prevalence and PCR Detection of *Salmonella* spp. and *Escherichia coli* in Water Used during Live Transportation of Climbing Perch (*Anabas testudineus*) in Bangladesh

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Abstract. This research investigated the incidence of two foodborne pathogens, *Salmonella* spp. and *Escherichia coli* in water used during live transportation of climbing perch (*Anabas testudineus*). Experiments were conducted in three commercially important fish supply channels of Bangladesh, starting from an important production area, Muktagacha, Mymensingh to Dhaka (supply channel 1), Sylhet (supply channel 2), and Rajshahi (supply channel 3). Water samples were collected from 0 hours (at the time of loading) to reaching at the final destination (unloading points/ retail markets) at every 2 hours interval during transportation. To assess the prevalence of *Salmonella* spp. and *E. coli*, *Salmonella-Shigella* (SS) agar and Eosin methylene blue (EMB) agar plate counts were done. For confirmation and PCR detection, a total of 52 isolates were obtained from those cultured plates based on the colony characteristics. The finding showed a gradual increase in SS- and EMB agar plate counts in all the supply channels. Out of the 52 isolates, 10 (19%) were detected as positive for *Salmonella* spp., while 38 (73%) as positive for *E. coli* and the rest were unidentified. It was assessed that the pond waters of the cultured areas might be the primary sources of contamination of these two foodborne pathogens.

Keywords: Live transportation; Climbing perch; *Salmonella*; *Escherichia coli*; PCR detection.

1. Introduction

Transportation of fish in live condition is a common practice and the fish farmers' transport fish for various purposes and for variable periods of time (Stieglitz *et al*., 2012). Compared with fresh, chilled or frozen product, live aquatic organisms are regarded as products of higher commercial value as it maintains the better freshness and quality (Araujo *et al*., 2020). Live transportation of fishes before retailing, provide a substantially higher prices and reduce the processing costs (Reynisson *et al*., 2009). There are two conventional live fish transport strategy- namely open containers and closed containers delivery (Amend *et al*., 1982; Das *et al*., 2015). Similarly in Bangladesh, fish in live condition is usually transported either "open truck system" or "tank system" (Rajts *et al*., 2020). In case of the "open truck system", a plastic/ tarpaulin is usually placed on the truck bed to hold water and here the water volume varies with the carrying capacity of the truck. A certain percentage of live fish are transported in water-filled plastic containers where each container contains 35-40 kg of fish (Alam *et al*., 2010). The climbing perch (*Anabas testudineus*) locally known as 'Koi' is an important air-breathing freshwater species widely distributed in small rivers, canal and swamp of Bangladesh (Mijkherjee *et al*., 2002). The species is considered as a valuable table fish for sick and convalescents, as it is a great source of protein with a high amount of iron and copper, which are mostly needed for hemoglobin synthesis (Sarma *et al*., 2010). In Bangladesh, commercial farming of this fish in the pond has become a very popular practice after the development of its induced breeding technique and mass production of seeds (Chhanda *et al*., 2019). Because of the consumers' preferences, this fish is commonly transported to the retail markets as live condition, especially to the major metropolitan areas. In Mymensingh area, the fishes are usually harvested using a large seine net, keep in "hapas" (net made rectangular barriers) setting at the corner of the fish ponds for acclamation usually for about 2 hours before transportation (Bhuiyan *et al.,* 2022; Hossain *et al*., 2021). For transportation, plastic barrel (1000 L) is loaded to commercial trucks with maximum carrying capacity of 5.17 tons. Plastic barrels are filled with 500 L of groundwater and each barrel was filled with 35 kg of fish approximately (on average 3 fishes per kg weight) and a maximum of 40 barrels are placed on each of the truck. No water additives, aeration facilities, and water exchange was practiced throughout the transportation (Hossain *et al*., 2021).

Bacteria are ubiquitous in the aquatic environment (Allen *et al*., 1983). Food from aquatic environments especially fish from aquaculture have been recognized as a major vehicle of foodborne pathogens to humans (Hradecka *et al*., 2008; IAEA, 2005). Human infections and intoxications caused by pathogens transmitted from fish are quite common and several species as *Salmonella* spp., *Staphylococcus* spp., *Vibrio* spp., *Aeromonas* spp., *Escherichia coli*, *Vibrio parahaemolyticus*, *Vibrio cholerae*, *Staphylococcus aureus*, and *Listeria monocytogenes* has been isolated from fish responsible for serious health hazards to the fisherman, fish handlers and finally to the consumers (Novotny *et al*., 2004; Hassan *et al*., 1994). The two most prevalence enteric pathogens over the world are *Salmonella* spp. and *E. coli* where about 12% of the food poisoning outbreaks associated with fish consumption are caused by *Salmonella* spp. and according to the Brazilian surveillance service, after *Salmonella* spp. and *Staphylococcus aureus*, *E. coli* is the next etiological agent mostly liable for foodborne diseases (Da Silva *et al*., 2010; Carmo *et al*., 2005).

From aquaculture ponds *Salmonella* spp. and *E. coli* has been isolated in Bangladesh along with many other countries of the world (Ava *et al*., 2020; Haider *et al*., 2007). These two pathogens also indicate the status of biosecurity measures as well as the sanitary condition of the aquaculture ponds and subsequent supply channels. Based on all of these above facts and findings, here we hypothesized that although groundwater is used to transport the fishes, these two pathogens will be detected from the samples of the transport water as well as from the cultured pond waters. We also assumed that as transportation progress, their counts will gradually increase. So, the objective of this study was to verify these hypotheses. Three supply channels of live climbing perch transportation were selected and sub-samples were collected from the beginning (at 0h of loading) of the supply channel to the end/ final destination (at point of unloading).

2. Materials and Methods

2.1 Geographical Location of the Supply Channels

The study was carried out in three supply channels of climbing perch in Bangladesh. All the channels started from Muktagacha upazilla (24°44′01″N, 90°20′36″E) under Mymensingh division of Bangladesh to Showarighat, Dhaka

(23°42′25″N, 90°24′34″E), supply channel 1; to Poschim Kazir Bazar, Sylhet (24°88′80″N, 91°86′40″E), supply channel 2; and Shaheb Bazar, Rajshahi (24°21'53″N, 88°35'66″E), supply channel 3 (Fig. 1). The samplings were done from July to September, 2019.

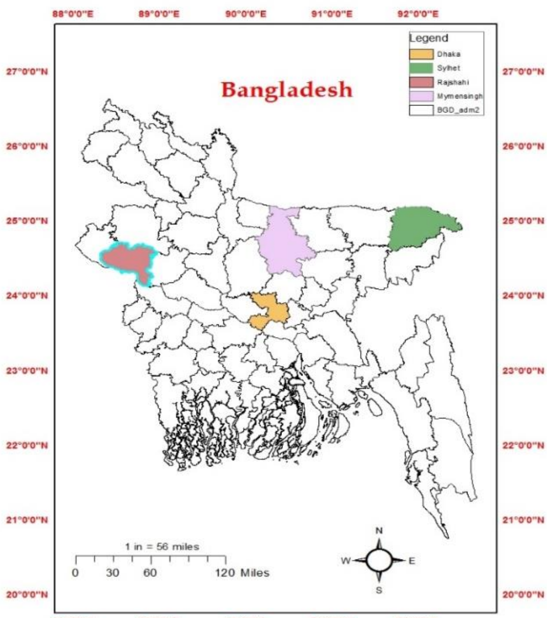

Fig. 1. Location of the studied supply channels of live climbing perch (*Anabas testudineus*) in Bangladesh. (Channel 1: Muktagacha, Mymensingh to Showarighat, Dhaka; Channel 2: Muktagacha, Mymensingh to Poschim Kazir Bazar, Sylhet; Channel 3: Muktagacha, Mymensingh to Saheb Bazar, Rajshahi). Geographical Information System (GIS) was used to extract images from DIVA-GIS. The development of map was done by ArcMap version 10.5.

2.2 Harvest, Post-harvest Handling of Fish for Transportation and Subsample Collection

Harvest of the fish was usually done at the late afternoon (from commercial climbing perch farms) for transportation at the following night. The details post-harvest preparation and procedures for transportation of climbing perch has been described in (Hossain *et al*., 2021). The fishes were captured using a large seine net and acclimated in a "hapa" (net made rectangular barriers measuring 3m × 2m × 1m) for about 2 hrs before loading. The fishes were transported in plastic barrels of 1000 L capacity loaded in a truck, which were filled with 500L of ground water and about 35 kg of fishes.

For sample collection, necessary sampling materials like beakers, volumetric flasks, tips, plastic containers, test tube, physiological saline, test tube, L-shaped glass rod, micropipette, hand gloves etc. were thoroughly washed and sterilized. SS- and EMB-agar plates were prepared in the Fisheries Microbiology Laboratory, Bangladesh Agricultural University by using SS- and EMB-agar media (Himedia, India). Prepared plates and other sampling materials/ tools were carried within a portable ice box (~4ºC) to the loading points. Travelling on the same vehicles used for the transportation of climbing perch was made to follow the changes in the counts and prevalence of *Salmonella* spp. and *E. coli* during transportation.

Subsamples of water were collected randomly in triplicate from the mid layer of the fish containing plastic barrels and kept in the previously sterilized plastic bottles (250 ml) started from 0h (at the time of loading fish to the truck) up to reach to the unloading points (desired fish retail markets) at every 2 hours interval. This approach allowed us to track the bacterial growth; decline or any fluctuations within the live fish transportation system/ transport water over time. During each sampling, water temperature was recorded using a glass thermometer and measured as °C. In order to assess the probable sources and prevalence of *Salmonella* spp. and *E. coli*, water samples were also collected from different cultured ponds of the sampling areas. The subsamples were divided into 3 groups and described under 3 collection sites, designated as collection point 1, 2, and 3. In this case, water samples were collected randomly in triplicate from different spots of the ponds. Subsequent preparation and plating was carried out onsite immediately after collection of the water samples as described to the next step.

2.3 Sample Preparation, Culture on Agar Plates and Quantification

One ml of collected water sample was transferred to a test tube containing 9 ml of previously prepared and sterilized physiological saline (0.85% w/v NaCl) with a micropipette (Kang *et al*., 2018). The test tube was shaken thoroughly for mixing and 10-fold serial dilutions were prepared as 10^{-1}, 10^{-2}, 10^{-3}. Then 0.1 ml of the above dilutions were pipetted out and transferred aseptically to the previously prepared plate count agar plates (for bacterial viable counts) and SS- and EMB-agar plates (for SS- and EMB-agar plate counts) with replication of each dilution, and spreaded on the surface of the media using a L-shaped glass rod until the samples were dried out. All the cultured plates were then covered with aluminum fuel and kept in a specimen transport box until transferred to the Fisheries Microbiology Laboratory, Bangladesh Agricultural University, Mymensingh, Bangladesh. The plates were then incubated at 30°C for 48 hours (for bacterial viable counts) and at 37°C for 36 hours (for SS- and EMB-agar plate counts). Finally, bacterial viable counts, SS- and EMB-agar plate counts were calculated by using the following formula-

cfu/ml = no. of colonies on petridish × 10 × dilution factor.

2.4 Isolation and Identification of *Salmonella* spp. and *Escherichia coli*

The isolation and identification of *Salmonella* spp. and *E. coli* was carried out based on culture on the SS- and EMB- agar plates described in (Haider *et al*., 2007) with slight modification. For this purpose, bacterial colonies developed on SS- and EMB-agar plates were collected (Fig. 2). Based on the colony characteristics, 3-5 representative colonies of each type were then purposively

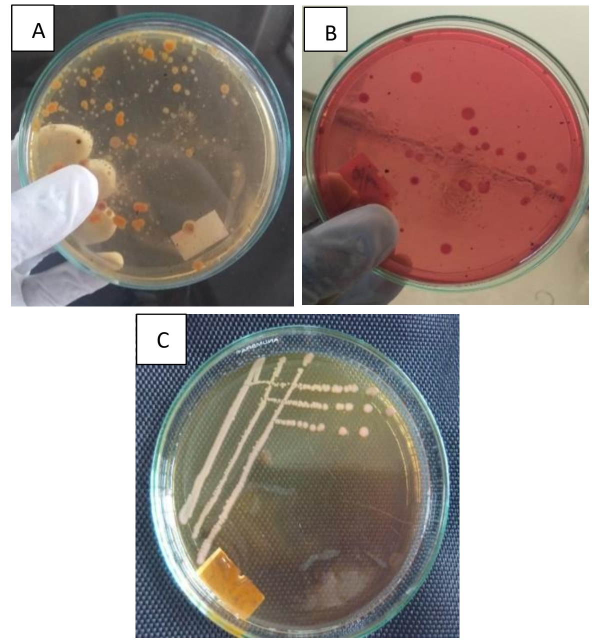

Fig. 2. Culture and growth of bacteria onto selected agar media conducted to detect *Salmonella* spp. and *Escherichia coli* in water used during live transportation of climbing perch (*Anabas testudineus*) in Bangladesh; A) suspected colonies of *Salmonella* spp. onto SS-agar medium, B) growth of *Escherichia coli* onto EMB-agar medium, and C) well-separated colonies of the targeted bacteria obtained after streaking onto SS-agar medium.

streaked on SS-agar (Himedia, India). After that plates were incubated aerobically at 37°C for 24 hours and well isolated colonies were observed. Repeatedly streaking was performed to get well separated colonies wherever necessary (Fig. 2). On the SS-agar plates, colonies with black-center, having opaque color or colorless characteristics were presumptively considered as indicative of *Salmonella* spp., and colonies with cream or pink to red color were presumptively considered as indicative of *E. coli*. The final confirmation of the isolation of *Salmonella* spp. and *E. coli* was performed by polymerase chain reaction (PCR) targeting the specific invA gene of *Salmonella* spp. and partial 16S rRNA gene of *E. coli*.

2.5 Extraction and Amplification of Bacterial DNA

For PCR, genomic DNA was extracted from *Salmonella* spp. and *E. coli* suspected pure cultures (isolates) by the boiling method described by (Rawool *et al*., 2007). In brief, a pure colony was put into an Eppendorf tube containing 100 µL of deionized water and gently vortex, followed by boiling and cooling for 10 min during each step. Finally, genomic DNA was collected after centrifugation for 10 min and stored at -20°C for further use.

Detection of *Salmonella* spp. invasive encoding gene and partial 16S rRNA gene of *E. coli* was done by using thermal cycler (ABI 2720, Applied Biosystems, Singapore). PCR primers and conditions used in the current study are provided in (Table 1) with the expected product size. Total PCR reaction mixture was 25 µl, having 12.5 µl 2× Master Mix (Promega, Madison, WI, USA), 1.0 µl of forward primer (10 pmol/µl), 1.0 µl of reverse primer (10 pmol/µl), 5.0 µl of DNA template, and 5.5 µl of nuclease-free water. After completion, the amplified PCR products were analyzed by gel electrophoresis (Cleaver Scientific, UK) using 1.5% agarose gel in 50× Tris-Acetic acid EDTA

Table 1. Primers used for the detection of *Salmonella* spp. and *Escherichia coli* from the water used during live transportation of climbing perch (*Anabas testudineus*) at different supply channels of Bangladesh and PCR conditions.

Bacteria	Target Gene	Name of Primer	Primer sequence (5`-3`)	PCR conditions	Amplicon size (bp)	References
Salmonella spp.	*invA*	InvA F	ATCAGTACCAGTCGTCTTATCTTGAT	Initial denaturation: 94°C for 5 min Denaturation: 94°C for 30 sec	211	(Ogunremi *et al*., 2017)
		InvA R	TCTGTTTACCGGGCATACCAT	Annealing: 52°C for 2 min Extension: 72°C for 45 sec Final extension: 72°C for 5 min Cycles: 30		
E. coli	16S rRNA	EC-1	GACCTCGGTTTAGTTCACAGA	Initial denaturation: 94°C for 5 min Denaturation: 94°C for 45 sec	585	(Hassan *et al*., 2014)
		EC-2	CACAGCTGACGCTGACCA	Annealing: 52°C for 45 sec Extension: 72°C for 1 min Final extension: 72°C for 5 min Cycles: 30		

(TAE) buffer. Amplicons were stained by ethidium bromide (0.5 μg/ml) and visualized under an ultraviolet trans-illuminator (Biometra, Germany). A 100 bp DNA ladder (Promega, Madison, WI, USA) was used as a molecular weight marker of the PCR amplicons.

2.6 Statistical Analyses

All the generated data and the results of laboratory investigations were entered, edited, coded, and analyzed using Microsoft Office Excel (2013). The quantitative values of bacteria were obtained using the formulae mentioned before. The error bars in the graphs were obtained by determining the standard deviations (SDs) of the triplicated values using Microsoft Office Excel (2013). A one-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test was conducted to evaluate the significant difference in viable bacterial count, SS, and EMB agar plate counts among the different sampling channels at 5% ($p<0.05$) level of significance through SPSS (version 26).

3. Results

3.1 Length of the Supply Channels and Changes in Temperature of the Transport Waters

The distances between the loading points to the unloading points were about 140 km, 305 km, and 230 km, respectively for the supply channel 1, channel 2, and channel 3. It took about 6 hrs, 8 hrs, and 8 hrs to reach the destination in the case of supply channel 1, 2, and 3, respectively due to variations in traffic conditions along the route.

The temperature of the transport waters were quite similar among the supply channels and varied between 29-31 °C regardless of the sampling periods.

3.2 Changes in Bacterial Viable Counts, SS- and EMB-ager Plate Counts in Water Used during Live Transportation

Bacterial viable counts demonstrated an upward trend with the duration of transportation. In channel 1, within 6 hours of transportation, the counts increased from

$(0.64 \pm 0.17)\times10^4$ cfu/ml to

$(31.01 \pm 11.55)\times10^4$ cfu/ml

While after 8 hours of transportation in channels 2 and 3, it increased from $(0.56 \pm 0.16)\times10^4$ cfu/ml to $(47.52 \pm 19.23)\times10^4$ cfu/ml and $(0.69 \pm 0.04)\times10^4$ cfu/ml to $(41.01 \pm 17.42)\times10^4$ cfu/ml, respectively. However, statistical analysis revealed no significant difference ($p > 0.05$) in viable bacterial counts among the studied supply channels at the same period of transportation (Fig. 3 and supplementary Table S1).

The average SS-agar plate counts were $(0.13 \pm 0.01)\times10^4$, $(0.21 \pm 0.03)\times10^4$, and $(0.12 \pm 0.05)\times10^4$ cfu/ml at the beginning (at 0 h) in case of supply channel 1, channel 2, and channel 3, respectively. Regardless of the supply channels, a gradual increase in SS-agar plate counts were observed in all the cases that were $(1.06 \pm 0.06)\times10^4$, $(1.37 \pm 0.07)\times10^4$, and $(1.28 \pm 0.11)\times10^4$ cfu/ml, respectively in channel 1, channel 2, and channel 3 at the final destination before the periods of unloading (6h, 8h, and 8h, respectively in case of channel 1, channel 2, and channel 3). Although bacterial counts on SS agar varied significantly ($p < 0.05$) among the supply channels at 0h, 2h, and 4h but it was insignificant ($p > 0.05$) at 6h, and 8h of transportation (Fig. 3 and supplementary Table S2). Similar tendencies, *i.e.* gradual increase in EMB- agar plate counts were also observed in all of the studied supply channels. The initial averages of EMB- agar plate counts were $(0.23 \pm 0.04)\times10^4$ cfu/ml, $(0.22 \pm 0.05)\times10^4$ cfu/ml, and $(0.13 \pm 0.03)\times10^4$ cfu/ml, respectively in channel 1, channel 2, and channel 3 which were finally increased to:

$(1.49 \pm 0.08)\times10^4$ cfu/ml, $(1.8 \pm 0.09)\times10^4$ cfu/ml, and $(1.45 \pm 0.05)\times10^4$ cfu/ml, respectively. However, a significant variation ($p < 0.05$) of EMB agar plates count were observed among the studied supply channels at 2 h, 4 h, 6 h, and 8h of transportation (Fig. 3 and supplementary Table S3).

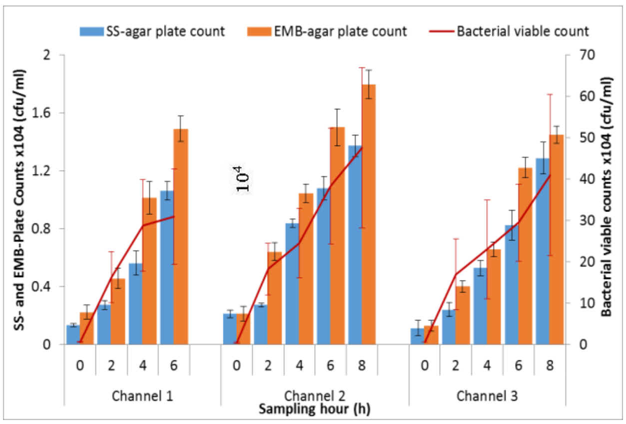

Fig. 3. Comparison in changes of SS- and EMB-agar plate counts (columns) with bacterial viable counts (lines) of water used during live transportation of climbing perch (*Anabas testudineus*) at different supply channels of Bangladesh (cfu = colony forming unit). The error bars are indicating the standard deviations (SDs) of the triplicated values.

3.3 PCR Detection of Salmonella spp. and E. coli in Water Used during Live Transportation

In the present study, for PCR detection of *Salmonella* spp. and *E. coli* from water used during live transportation of climbing perch was done after conventional culture based screening of isolates. A total number of 52 isolates were collected from all the three supply channels. Two sets of primers such as, InvA (211 bp) targeting invA genes of *Salmonella* spp., and EC (585 bp) targeting parts of 16s rRNA genes of *E. coli* were used during PCR. In case of sampling channel 1, out of 14 isolates, 2 (14.28%) isolate were detected as positive for *Salmonella* spp. (Fig. 4A), while 10 (71.42%), isolates as positive for *E. coli* (Fig. 4B). In case of sampling channel 2, out of 21 isolates, 5 (23.80%) were detected as positive for *Salmonella* spp. (Fig. 4C), while 15 (71.43%) as positive for *E. coli* (Fig. 4D). And finally in case of supply channel 3, 17 isolates were obtained of which 3 (17.64%) were found positive for *Salmonella* spp. (Fig. 4E), and 13 (76.47%) for *E. coli* (Fig. 4F). Overall, out of 52 isolates, 10 (19%) isolates were detected as positive for *Salmonella* spp., while 38 (73%) for *E. coli*, and 4 (8%) isolates were not provided any band after PCR, recognized as unidentified (Table 2 and Fig. 5).

3.4 SS- and EMB-Ager Plate Counts of the Cultured Ponds of the Studied Areas

In order to assess the SS- and EMB- agar plate counts of the climbing perch cultured ponds, water samples were collected from 13 different ponds of three particular collection points. Following established procedures (Haider *et al.*, 2007) the water samples were plated, and incubated at 37°C for 36 hours. In case of collection point 1, 4 sampling ponds were assessed in which the average SS-agar plate counts were about $(0.35 \pm 0.08)\times10^4$ cfu/ml, $(0.43 \pm 0.07)\times10^4$ cfu/ml, $(0.41 \pm 0.10)\times10^4$ cfu/ml, $(0.45 \pm 0.14)\times10^4$ cfu/ml, respectively, while average EMB-agar plate counts were $(0.64 \pm 0.06)\times10^4$ cfu/ml, $(0.77 \pm 0.08)\times10^4$, $(0.49 \pm 0.07)\times10^4$, $(0.78 \pm 0.12)\times10^4$ cfu/ml respectively. Furthermore, at collection points 2 and 3, water samples were collected from 5 and 4 cultured ponds, respectively. The average SS- and EMB-agar plate counts for collection point 2 were $(0.45 \pm 0.07)\times10^4$ cfu/ml, and $(0.69 \pm 0.06)\times10^4$ cfu/ml, respectively. However, at the collection point 3, the counts slightly varied with $(0.41 \pm 0.10)\times10^4$ cfu/ml for SS-agar plates and $(0.72\pm 0.12)\times10^4$ cfu/ml for EMB-agar plates (Fig. 6). The results showed that all the pond water gave counts on SS- and EMB-agar plates and the counts of the pond waters were somewhat close to the initial (0 h) counts of the supply channels (Fig. 3 and 6).

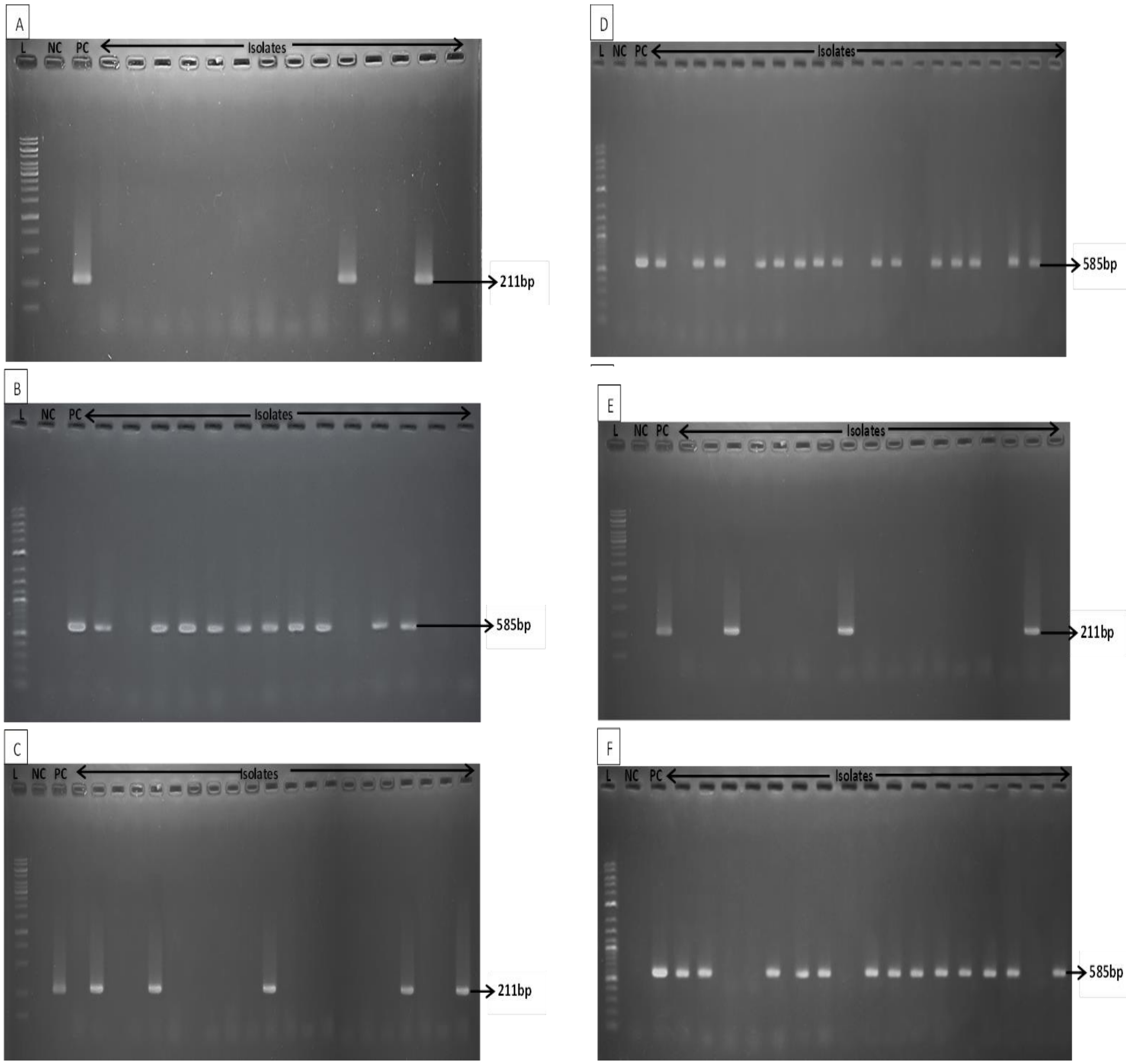

Fig. 4. Amplification of *invA* gene of *Salmonella* spp. (211 bp) and partial 16S rRNA gene of *E. coli* (585 bp) isolates recovered from different supply channels of climbing perch (*Anabas testudineus*); A) *Salmonella* spp. isolates from supply channel 1, B) *E. coli* isolates from supply channel 1, C) *Salmonella* spp. isolates from supply channel 2, D) *E. coli* isolates from supply channel 2, E) *Salmonella* spp. isolates from supply channel 3, and F) *E. coli* isolates from supply channel 3. In the lanes, L = ladder, NC = negative control, and PC = positive control.

Table 2. Summary of the obtained isolates, PCR analyses and detection of *Salmonella* spp. and *Escherichia coli* from the water used during live transportation of climbing perch (*Anabas testudineus*) at different supply channels of Bangladesh.

Supply channel	Time required to final destination (h)	No. of collected isolates	No. of isolates tested positive for *Salmonella* spp.	No. of isolates tested positive for *E. coli*	No. of identified isolates	No. of unidentified isolates	Incidence of *Salmonella* spp. (%)*	Incidence of *E. coli* (%)*	Percentage (%) of unidentified isolates*
1	6	N=14	2	10	12	2	14.28	71.42	14.28
2	8	N=21	5	15	20	1	23.80	71.43	4.76
3	8	N=17	3	13	16	1	17.64	76.48	5.88

Note. N=Total number of isolates obtained, * % = (No. of isolates found positive or unidentified /N) ×100

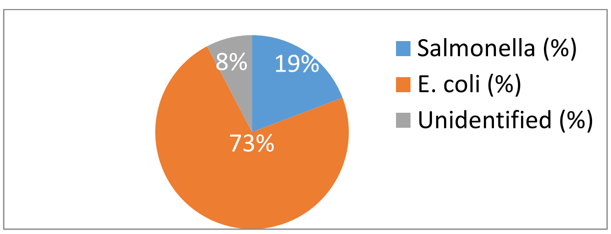

Fig. 5. Percentage of *Salmonella* spp. and *E. coli* positive isolates obtained from the water used during live transportation of climbing perch (*Anabas testudineus*) at different supply channels of Bangladesh; % unidentified indicating those did not give any bands for the used primer sets.

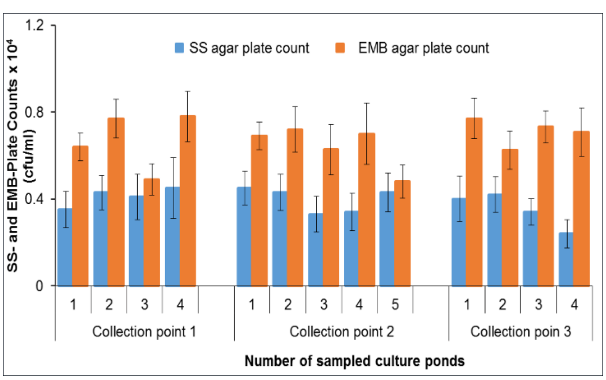

Fig. 6. SS- and EMB-agar plate counts of the water collected from the climbing perch (*Anabas testudineus*) cultured ponds of three different collection points in the studied areas of Bangladesh. The error bars are indicating the standard deviations (SDs) of the triplicated values.

4. Discussion

We hypothesized that these two pathogens *Salmonella* spp. and *Escherichisa coli* will be detected from the water samples used during live transportation of fish and cultured ponds, and their counts will gradually be increased in water used during live transportation of fish. The detection of *Salmonella* spp. and *E. coli* from live climbing perch transport water is a great concern due to its potential to cause enteric diseases, which are globally recognized as foodborne zoonoses (Oh *et al*., 2011).

Both culture based (in selective media) and molecular based approaches were used for identification and confirmation of these two bacteria. Several studies have been applying for the isolation and identification of *Salmonella* and *E. coli* from the food samples. For culture based identification several selective media are used. *Salmonella* spp. produce opaque, translucent and colorless colonies on *Salmonella-Shigella* (SS) selective agar while colorless, pale, transparent colonies on MacConkey agar (Rather *et al*., 2013). *E. coli* on the other hand, appear as pink colonies (lactose fermentation) on MacConkey's agar medium, whereas, a characteristic greenish metallic sheen on EMB agar medium (Shahzad *et al*., 2013; Abd El-Aziz *et al*., 2014). PCR based molecular methods for detection of *Salmonella* spp. and *E. coli* was performed in this study. However, PCR detection provides more confirmatory results in a short time with high accuracy. It is important to note that primers used in this study for detection of *Salmonella* spp. and *E. coli* are known as very fast, unique, sensitive in detecting by PCR examination technique (Yanestria *et al*., 2019). For this reason, polymerization of invA gene has been popularly using for the detection of *Salmonella* from different types of samples (Malorny *et al*., 2003; Van Blerk *et al*., 2011; Aliviameita *et al*., 2011; Ogunremi *et al*., 2017; Yanestria *et al*., 2019). Seel *et al*., (2016) conducted a study on identification of *Salmonella* spp. from *Anabas testudineus* through molecular detection targeting the invA gene. While for *E. coli*, amplifying genus specific 16S rRNA gene by PCR using EC-585bp primer give confirmatory results (Maheux *et al*., 2009; Uddin *et al*., 2019).

Several pathogenic genera of bacteria (either for fish or human being) such as *Aeromonas* spp., *Vibrio* spp., *Salmonella* spp., and *E. coli* has been isolated from the commercial climbing perch farming areas (Zaman *et al*., 2013). However, there is scarcity of information on the prevalence of *Salmonella* spp., and *E. coli* in water used during live transportation of fish in Bangladesh as well as in the world. Also, there is no data about their quantitative changes during live transportation of fishes in Bangladesh. This study is the first attempt in Bangladesh has made to assess the prevalence and PCR based detection of *Salmonella* spp. and *E. coli* in water used during live transportation of climbing perch. Previously, it was reported (Hossain *et al*., 2021) that regrowth of bacteria is occurred and the viable counts gradually increase in the water used during live transportation of climbing perch.

In aquaculture, the health of fish is mostly influenced by the water conditions of a fish farm (Roalkvam *et al*., 2019). Fish is known to harbour bacteria of public health importance. Bacterial loads especially enteric bacterial population of the harvested fish reflects the microbial water quality of the pond. The supplying of live fish is routinely delivered by small volume of water. The results of the study showed that the water of climbing perch cultured ponds gave enteric bacterial counts on SS- and EMB-agar plates. This is may be because of introduction of or contamination by animal excreta/ wastes to the fish producing ponds or fecal contamination of the pond water from the areas (Chowdhury, 2010). Sewage contamination or waste water contamination from human toilets are reported to contain bacterial and other parasitic pathogens (Kay *et al*., 2008) are also contaminate the pond water during heavy rain and surface runoff. Moreover, several authors (Ava *et al*., 2020; Chhanda *et al*., 2019; Hossain *et al*., 2017; Zaman *et al*., 2013) detected *Salmonella* spp. and *E. coli* from climbing perch cultured pond waters.

Salmonella spp. and *E. coli* found in the intestianl tracts of animals and can shed in the faeces which can contaminate food, soil and water. *Salmonella* spp. can also survive for months in the soil. Previous reports also showed that *Salmonella* spp. can survive in the environment for several years (Gorski *et al*., 2011). Although, it cannot multiply in water because of sufficeient nutrients, it was found that in the groundwater they may remain as viable state (Pronk *et al*., 2006). *Salmonella* spp. and *E. coli* can introduce to the fishes from the contaminated waters. After contamination, fish itself may become host of *Salmonella* with no clinical signs (Bibi *et al*., 2015). Previous reports also showed a high prevalence of *Salmonella* spp. in fish intestines, skin, gills (Nwiyi and Onyeabor, 2012) and fish muscles (El-Olemy *et al*., 2014). In addition to the *Salmonella* spp. and *E. coli*, there are so many other enteric bacteria, including pathogenic species are naturally present in the freshwater, capable of growing there (Hendricks, 1972; Hendricks and Morrison, 1967). Accumulation of fecal materials and metabolic wastes within the waters can also enhance the growth of bacteria during climbing perch transportation (Hossain *et al*., 2021).

When fish are consistently exposed to the microorganisms present in the water bodies and fish itself is a source of bacteria (Mayer and Ward, 1991). For this reason, although groundwater is generally used for live transportation they may be contaminated from the fish itself. Morover, groundwater can also be contaminated by a wide range of pathogens including enteric groups as reported before (Li *et al*., 2009; John and Rose, 2005). Pathogenic bacteria such as *Salmonella* spp, *Shigella* spp, *Vibrio cholerae* and *E. coli* being shed in human and animal faeces ultimately find their way into water supply through seepage of improperly treated sewage into groundwater (Dipaola, 1998). Three important members of the family Enterobacteriaceae *i.e. E. coli*, *E. aerogenes*, *Salmonella* and *Klebsiella* had identified in groundwater by (Suthar *et al*., 2009). Even in developed countries, contamination of groundwater by microbial pathogens had also been documented (Borchardt *et al.*, 2004; Bockelmann *et al.*, 2009). Another possible source of these pathogenic bacteria can be the transport containers used during live transportation. In Bangladesh, fish transporters used plastic barrels that are often uncleaned and being used frequently without washing and cleaning after transporting a batch. Even Microorganisms can survive and thrive in the sand of fish-holding plastic water tanks and (Momba and Kaleni, 2002) isolated *Escherichia coli*, *Salmonella* and *Clostridium perfringens* from plastic water containers.

So, the gradual increase of the SS- and EMB- agar plate counts of the water used during live transportation of climbing perch may be because of longer exposure of the fishes to the limited amount of water in the transporting tanks as well as excretory activities for longer period of time. Anyway, it should be noted here that SS- and EMB-agar support the growth of some other enteric bacteria other than *Salmonella* spp. and *E. coli*, thus the SS- and EMB-agar plate counts are not necessarily indicating the growth of only *Salmonella* spp. and *E. coli*. However, further intensive investigation regarding the growth and multiplication of enteric bacteria in the presence of a higher amount of excretory materials (also nutrients for some bacteria) within the system should be taken into consideration for further clarification of the reasons of gradual increase of SS- and EMB-agar plate counts.

5. Conclusion

The findings of this study indicate that the water used during live transportation of climbing perch contained bacteria of enteric origins. The PCR detection of the isolates showed that pathogenic groups like *Salmonella* spp. and *E. coli* are also included to this enteric group. This is the first report on the prevalence of *salmonella* spp. and *E. coli* in water used during live transportation of fish in Bangladesh. For the sake of consumers' safety issues, the rules of the good aquaculture practices and good handling practices should be taken into consideration.

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Supplementary Data

Table S1. Variability in viable bacterial counts of water used during live transportation of climbing perch (*Anabas testudineus*) at different supply channels of Bangladesh (cfu = colony forming unit).

Time (h)	Bacterial viable counts (mean ±sd)× 10^4 cfu/ml		
	Channel 1	Channel 2	Channel 3
0	0.64 ± 0.17[a]	0.56 ± 0.16[a]	0.69 ± 0.04[a]
2	16.32 ± 6.10[a]	18.27 ± 6.16[a]	16.98 ± 8.53[a]
4	28.85 ± 11.08[a]	24.55 ± 8.42[a]	23.07 ± 11.90[a]
6	31.01 ± 11.55[a]	38.52 ± 13.99[a]	29.52 ± 9.25[a]
8	-	47.52 ± 19.23[a]	41.01 ± 17.42[a]

Values are expressed as mean ±SD. Means in the same row (counts at the same period of transportation) with a same superscript are not significantly (P>0.05) different.

Table S2. Variability in SS- agar plate counts of water used during live transportation of climbing perch (*Anabas testudineus*) at different supply channels of Bangladesh (cfu = colony forming unit).

Time (h)	Bacterial counts SS agar (mean ±sd)× 10^4 cfu/ml		
	Channel 1	Channel 2	Channel 3
0	0.13 ± 0.01[b]	0.21 ± 0.03[a]	0.12 ± 0.05[b]
2	0.24 ±5.686[b]	0.36±2.00[a]	0.23 ±3.215[b]
4	0.69±16.166[ab]	0.86 ±4.163[a]	0.58 ±2.082[b]
6	1.06 ± 0.06[a]	1.09±2.517[a]	1.12 ±3.00[a]
8	-	1.37 ± 0.07[a]	1.28 ± 0.11[a]

Values are expressed as mean ± SD. Means in the same row (counts at the same period of transportation) with different alphabetical superscripts are significantly (p < 0.05) different.

Table S3. Variability in EMB- agar plate counts of water used during live transportation of climbing perch (*Anabas testudineus*) at different supply channels of Bangladesh (cfu = colony forming unit).

Time (h)	Bacterial counts on EMB agar (mean ±sd)× 10^4 cfu/ml		
	Channel 1	Channel 2	Channel 3
0	0.23±1.528[a]	0.22±1.041[a]	0.13±1.163[a]
2	0.48±4.041[a]	0.61 ±1.528[a]	0.34 ±2.646[b]
4	1.09 ±4.041[a]	1.02±2.646[a]	0.65 ±6.245[b]
6	1.49±3.00[a]	1.37±4.509[a]	1.13±7.00[b]
8	-	1.83±7.024[a]	1.45±6.110[b]

Values are expressed as mean ± SD. Means in the same row (counts at the same period of transportation) with different alphabetical superscripts are significantly (p < 0.05) different.

انتشار وكشف PCR للسالمونيلا والإشريكية القولونية في المياه المستخدمة أثناء النقل الحي لسمك الفرخ المتسلق (*Anabas testudineus*) في بنغلاديش

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المستخلص. التحقيق في هذا البحث في حدوث اثنين من مسببات الأمراض المنقولة بالغذاء، السالمونيلا. والإشريكية القولونية في المياه المستخدمة أثناء النقل الحي لسمك الفرخ المتسلق (*Anabas testudineus*). أجريت التجارب في ثلاث قنوات إمداد سمكية مهمة تجاريًا في بنغلاديش، بدءًا من منطقة إنتاج مهمة، موكتاجاتشا، وميمينسينغ إلى دكا (قناة الإمداد ١)، وسيلهيت (قناة الإمداد ٢)، وراجشاهي (قناة الإمداد ٣). تم جمع عينات المياه من الساعة صفر (وقت التحميل) حتى الوصول إلى الوجهة النهائية (نقاط التفريغ/أسواق البيع بالتجزئة) كل ساعتين أثناء النقل. لتقييم مدى انتشار السالمونيلا النيابة. وتم إجراء تعداد أجار الإشريكية القولونية وأجار السالمونيلا– الشيغيلا (SS) وأجار أجار الميثيلين الأزرق (EMB) للتأكيد والكشف عن تفاعل البوليميراز المتسلسل، تم الحصول على إجمالي ٥٢ عزلة من تلك الصفائح المزروعة بناءً على خصائص المستعمرة. أظهرت النتائج زيادة تدريجية في عدد ألواح أجار-SS وEMB في جميع قنوات الإمداد. من بين ٥٢ عزلة، تم اكتشاف ١٠ (١٩٪) إيجابية لبكتيريا السالمونيلا، بينما ٣٨ (٧٣٪) إيجابية لبكتيريا الإشريكية القولونية والباقي لم يتم التعرف عليهم. وقد تم التقييم أن مياه البرك في المناطق المستزرعة قد تكون المصدر الرئيسي لتلوث هذين المسببين للأمراض المنقولة بالغذاء.

الكلمات المفتاحية: النقل الحي؛ تسلق الفرخ السالمونيلا. الإشريكية القولونية؛ كشف PCR.

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Estimation of Radon Released from Ktebban River, North Basrah City, by Using CR-39

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Abstract. In this work, closed can technique is used to estimate the radon and radium content in solid samples collected from Ktebban River, north Basrah City. The radon concentration in the studied solid samples was between 9.46±2.29 Bq.m^{-3} to 29.83±4.81 Bq.m^{-3}, so that the effective radium variation could be about 0.001 Bq.kg^{-1} to 0.004571 Bq.kg^{-1} since it was responsible for radon emanation in the air. These values considered as acceptable values when comparing worldwide and neighbors countries. The flux and exhalation per unit area and per unit mass arranged between 0.13Bq m^{-2} h^{-1} to 0.54Bq m^{-2} h^{-1} and 0.003Bq m^{-2} h^{-1} to 0.015Bq m^{-2} h^{-1}, respectively. These values are also lower than the reported worldwide limit. This could suggest that it is likely safe to use such sediments for building materials and other uses.

Keywords: Radon concentration, SSNTDs, effective Radium.

1. Introduction

Everything on the Earth's surface is constantly exposed to the effects of radiation from naturally radioactive materials, such as the eternal Earth's radioactive isotopes and what produce from them. Life arose and developed in ocean, humans were exposed to these radiations, whose level has remained almost constant since ancient times (Wilkenning *et al*., 1990).

Environmental radioactive pollution with radioactive materials occurs naturally, while concentrations increase above the natural conditions by nuclear or non-nuclear industries such as the phosphate oil and gas industries and throwing them as wastes into the environment without treatment (Regional training course *et al.*, 2014). One of these isotopes is radon. In general there are three of radon isotopes as a result of differences in radioactivity series. The one of these differences is in their half life times. The ^{219}Rn isotope has a half-life of $T_{1/2}$ =3.96s , ^{220}Rn has $T_{1/2}$ = 55.6 s and ^{222}Rn has a relatively long-lived half-life of $T_{1/2}$ = 3.82 days (Shikha Pervin *et al*., 2022). The concentration of radon gas follows the concentration of uranium and thorium in soil and rocks. This is because it results from the decomposition of these isotopes. Radon gas is dissolved in water, which is one of the products of Radium-226 (Alexandra *et al*., 2022), and its concentration changes depending on the source of the water, whether surface or underground, and according to its content of mineral salts and the nature of the water basin (Munaf *et al*., 2015). The concentration of radon is approximately of 0-185 Bq/l in surface waters such as lakes. Whereas in rivers and wells is about 185-3703 Bq/l, but in springs it reaches 37 Bq/l. Its concentrations may be high in the old groundwater, because of the accumulation of radon gas (Regional training course *et al*., 2000). The concentration of radon is related to the porosity of rocks, as well as to water-rich sandy interlayers in the sedimentary sequence (Xue Biying *et al*., 2021). Areas in which intermediate or acidic volcanic and plutonic rocks predominate are characterized by greater radon activity concentration in soils, rendering them radon-prone (Alonso, *et al*.,2019).

1.1 Aim of the Study

The aim of the study was to know the concentration of radon gas in the sediments of the Ktebban River, which branches off the Shatt Al-Arab River. The area is considered one of the areas of the food basket of the city of Basrah, and is inhabited by a large number of people spread across both banks of the river. The region is distinguished by the production of dates, as well as the cultivation of vegetables and dairy products, and these materials are considered a source of food for the people. The presence of a large power plant very close to the study area that operates with Oil products makes it important to know its impact through the waste it produces as a result of the work.

1.2 Study Area

The city of Basrah, located in southern Iraq, is considered the gateway into Iraq and to the word. It is considered the only city that contains Iraqi ports. In the past, the discharge that come to the Shatt al-Arab river was very high, which led to the flooding of agricultural lands on both sides of the river and get rid of its salts, making it a fertile agricultural land. One of these areas is the Ktebban River area within the coordinates of N:30º30″42′, E:47º45″35′ and N:30º30″43′, E:47º47″01′. Figure 1. Stefan Röttger *et al*., (2022) mentioned that the Ktebban River area is one of the areas of food baskets in the city of Basrah. The length of the river is approximately 7km and connects directly to the Shatt al-Arab river. It heads east through the agricultural lands and most of the residents of this area work in agriculture and animal husbandry so palm gardens are spread on both sides of the river. It connects the life's of the residents of Basrah City with the surrounding areas. On other side, the presence of vital facilities near the area about 5 km such as the oil production fields in the Bin Omar oil fields about 5 km approximately and business accompanying production and operating conditions. Some conditions in the crude oil production field may cause a certain amount of oil spills to be transferred into the environment and cause pollution. Therefore, it is important to monitor the area and create a basic data base in it.

2. Methodology

Most of the radon produced from marine sediment remains within the sediment grains in the bottom water. Many of fractions of radon escapes to the pore spaces, water and porosity (Hallvard *et al*., 2022). It dissolves through the water, depending on the grain size and location of its parent in grain (Duenas *et al*., 1997). The radon, ^{222}Rn, is produced by radioactivity of radium, ^{226}Ra. The ^{226}Ra decays to ^{222}Rn by emitting an Alpha particle (Florian Jorg A. *et al.*, 2022). The main mechanism of escape turns back energy of its atoms during the α decay of ^{226}Ra and diffusion through grain or water as shown in Fig. 2.

In this study, we use closed cylinder technique (Can technique) which is a plastic container vessels of volume (576.97cm3) with cross sectional area of 38.465 cm^2 (Fig. 3). The sediment samples were placed at the bottom of these vessels. The Can is completely sealed for about 27 to 28 days to allow the 238U and 226Ra to reach equilibrium between them (Ahmed *et al*., 2012). The radon gas concentration is given by equation 1.

$$C(t) = \frac{\rho}{K\,T} \quad (1)$$

Where: ρ is track density in Tr/cm^2, T is exposure time in day. K is the calibration factor in Tr. cm^{-2}.day^{-1}/Bq.m^{-3}. The radon concentration growth with the time (Musa *et al*., 2003). The exhalation rate is defined as the rate at which radon escapes from soil into the surrounding air, either per unit area or per unit mass of sample. The radon exhalation rate in terms of area is calculate from equation 2.

$$E_A = \frac{C\,V\,\lambda}{A\,T_{eff}} \quad (2)$$

Where, T_{eff} is the effective exposure time, which is related to the actual exposure time T and decay constant λ for ^{222}Rn, A is the area, *v i*s a volume over sample and *c* is concentration. The radon exhalation rate in terms of mass is calculate from the expression equation 3.

$$E_M = \frac{C\;V\;\lambda}{M\;T_{eff}} \text{ (Jabbar H. Jebur } et\ al.\text{, 2015)} \quad (3)$$

Where, E_M is the radon exhalation rate in term of mass (Bq.kg^{-1}.h^{-1}) and M is the mass of sample, *v* represented the volume over sample in Can.

The concentration of effective radium content in the sample could be calculated from:

$$C_{Ra} = \frac{\rho\;h\;A}{\mathrm{K}\,\mathrm{T_{eff}}\;M} \text{ (Munaf } et\ al.\text{, 2015)} \quad (4)$$

Where, T_{eff} is the effective exposure time, M is the mass of the sample in kg, A is the area of cross-section of the can in m^2, h is the distance between the detector and top the solid sample in meter, and K is the calibration factor for radon gas.

2.1 Sample Collection

The tools used in collecting samples differ depending on the areas from which samples were collected and on the nature of the area, whether it is a marine (or river) with shallow or deeper depths or land area. In the marine places, the speed of sea/river water currents (high or weak) was taken into account when retriving the samples. All of these conditions allowed us to use the appropriate tools for each area/sample of the study for later analysis. In the study area, the average water depths in the river are about 3-4 m, and the speed of the river currents is weak. Therefore, the sediment samples were collected using the Van Veen Grab Sampler (Fig. 4). This grab sampler allowed us to take surface sediment samples from the bottom of the river or the sea, which it is different in dimensions and weights. The grab sampler has the ability to collect bottom sediment samples with a penetration depth of approximately 10-20 cm.

Immediately after collection the samples were placed in 2 kg polymer bags, transported to the laboratory, and left at normal air temperature for several days to dry, after removal from the polymer bag. Then, samples were crushed to fine powders with sizes of 0.2 mm. Then it is placed in a special measuring box for the purpose of irradiation. The height of the sample in the can is about 5 cm and insure that the tightness of the canister. Samples in the closed canisters were left for 100 days to release radon gas and record emissions from the model via the detector located in the canister installed at a height of 10 cm from the base.

2.2 Chemical Etching

This is the most effective method for laying the size of the latent tracks produced by heavily ionized particles. Chemical etching is usually carried out in a thermostatically controlled bath at 70 °C. The etching time is every 7 hours for CR-39 detector (Loffredo, *et al*., 2022). The etching, which has been most commonly used for plastic detectors, is aqueous alkaline NaOH or KOH solution with concentration of 6.25 N in order to etch the CR-39 detectors, on metal container (holding many detectors) and attached to a wire and immersed into the etching solution within a beaker (Sahooa *et al*.,). The beaker is then placed in a temperature-controlled water path. At the end of the etching, the detectors are removed and washed under running tap water, to remove the etching residue from the etched pits. After drying, the detectors are counted under an optical microscope. The etched track diameters are typically a few μm in size and grow larger in size after prolonged etching (Dwived *et al*., 1997). The normality (N) of NaOH solution is calculated by using the following equation 4 (Alharbi *et al*., 2011).

$$N = \frac{m(g)}{V} \times \frac{1000}{M_W} \quad (5)$$

Where: *m(g)* is a mass of solid NaOH in grams. *V* is the volume weight in ml. M_W is the molecular weight of NaOH which is equal to 40. The track samples are shown in Figure 5.

3. Results and Discussions

The importance of the study area of the Ktebban River with respect of its natural radioactivity is a vital subject for the present study, because it is located in a vital area crowded by the industrial facilities, such as production of electric power. As well as its proximity to the irrigation channel carrying fresh water from the same area to the city of Faw through the city of Basrah. Also, this area is considered a food basket for the city of Basrah, and there are a number of people and villages who live in the area. In the Table 1 which explained the results of radon concentrations in the study area, the results showed that radon concentrations varied from 9.46±2.29 Bq m^{-3} to 29.83±4.81 Bq m^{-3}. Radon flux per unit area in Bq m^{-2} h^{-1} ranged from 0.13 Bq m^{-2} h^{-1} to 0.54 Bq m^{-2} h^{-1}. The mass exhalation rate in the sediment samples of this study ranged from 0.003 m Bq kg^{-1} h^{-1} to 0.015 m Bq kg^{-1} h^{-1}. The effective radium variation varied from 0.001 Bqkg-1 to 0.004571 Bqkg-1, and it is responsible for radon emanation into the air.

The distribution of radon concentration and effective radium in the study area along the river showed that the sample 15 has a higher concentration than in the other samples (Fig. 6-7). This place witnesses human activity in addition to agricultural activity, while in the other models they are less effective and the distribution of values is fluctuating. The positive correlation between Rn-222 and effective Radium Ra_{eff} was 87% as it is explained in Figure 8. The exhalation rate per unit area and per unit mass of radon concentration in the collected sediment samples is quite lower than those of the international limit. While the recorded effective radium values content in sediment samples taken from the same locations and with comparable to the global average value of radium in soil, we can recommend that the sediments of the study area may be safely used as building materials.

From this study, we can also recommend that the area is safe, as far the health hazard effects of radium and radon flux are concerned. These results could give a clear picture of the radon values through which they contribute to drawing the radiological map of the city of Basrah. From Table 2, comparison between the levels of radon concentrations recorded from sediments and soils in the study area and in many locations worldwide showed the study area has lower values than those recorded worldwide.

Fig. 1. Numbers represented distribution of the samples in the study area.

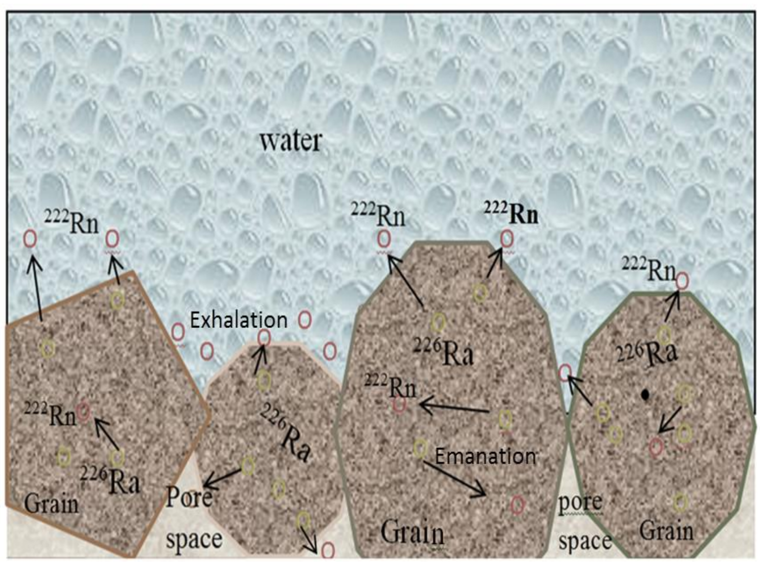

Fig. 2. Sketch of emanation and exhalation processes of 222Rn, depending on location of 226Ra atoms and soil moisture contents.

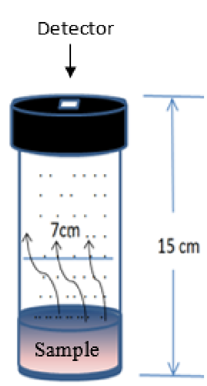

Fig. 3. Schematic diagram showing a closed can cylinder container used in this study.

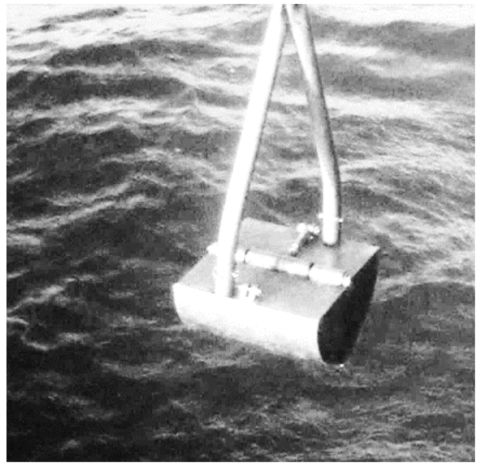

Fig. 4. The Van Veen Grab Sampler for collecting samples.

Table 1. Concentration of effective of Rn-222 and its emanation per unit mass and area.

NO.	**Rn-222 concentration in Bq/m^3 by SSNTDs**	**E_A in $Bq/m^2.h$**	**E_M in Bq/kg. h**	**Effective Ra in Bq/kg**
1	18.91±3.81	0.34	0.008	0.003181
2	15.45±5.22	0.28	0.008	0.00300
3	12.36±3.56	0.22	0.007	0.001711
4	12.74±4.56	0.23	0.007	0.0019
5	13.09±2.78	0.24	0.007	0.001837
6	14.84±6.11	0.27	0.008	0.0019
7	16.73±3.23	0.30	0.009	0.002281
8	13.56±4.23	0.25	0.007	0.0020
9	10.91±3.83	0.20	0.005	0.001727
10	9.94±3.58	0.19	0.005	0.001
11	9.46±3.38	0.17	0.005	0.00144
12	12.34±4.29	0.22	0.007	0.0018
13	14.55±2.15	0.26	0.008	0.001984
14	21.98±8.11	0.32	0.009	0.0030
15	29.83±4.81	0.54	0.015	0.004571
16	23.45±9.21	0.43	0.009	0.0040
17	17.46±3.65	0.32	0.010	0.002224
18	16.89±6.34	0.31	0.008	0.0020
19	16.73±4.23	0.30	0.008	0.002481
20	17.34±6.21	0.33	0.008	0.0026
21	19.64±2.42	0.36	0.010	0.00301
22	17.78±5.91	0.32	0.008	0.0027
23	16.01±3.16	0.29	0.008	0.002325
24	13.77±4.23	0.25	0.007	0.0020
25	11.64±3.42	0.21	0.005	0.001934
26	14.21±5.28	0.26	0.007	0.0020
27	17.46±3.58	0.32	0.009	0.002571
28	13.37±3.98	0.26	0.007	0.0021
29	9.46±2.29	0.17	0.004	0.001496
30	15.55±5.82	0.23	0.005	0.0021
31	19.6459±4.26	0.36	0.010	0.002854
32	19.11±6.21	0.34	0.008	0.0027
33	18.19±1.27	0.33	0.008	0.002986
34	12.32±4.95	0.27	0.007	0.0022
35	7.27±3.23	0.13	0.003	0.001144
36	11.45±4.48	0.21	0.007	0.0021

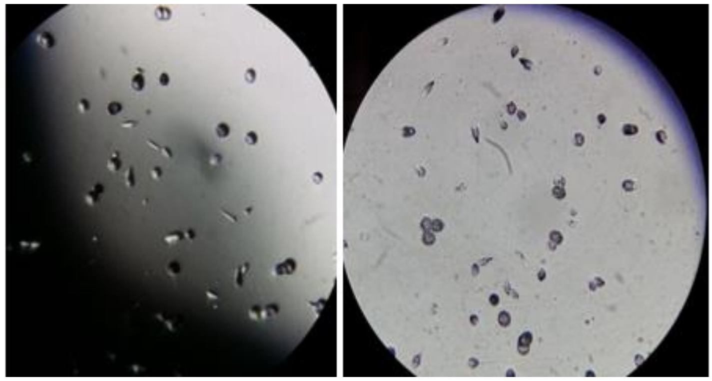

Fig. 5. Image showing the tracks of Alpha particles on detector.

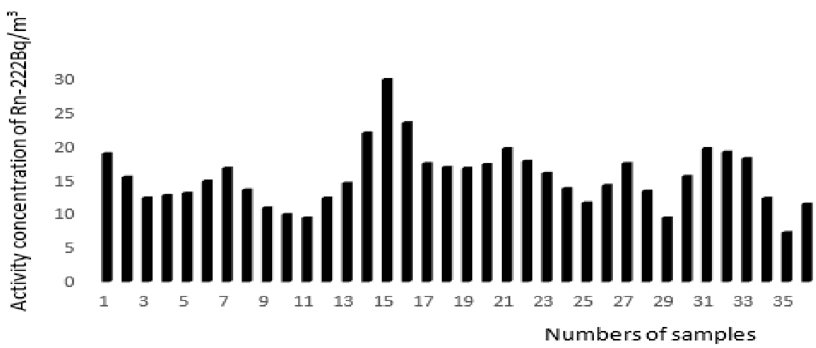

Fig. 6. Distribution of activity concentration of Rn-222 (Bq/m3) in the studied samples.

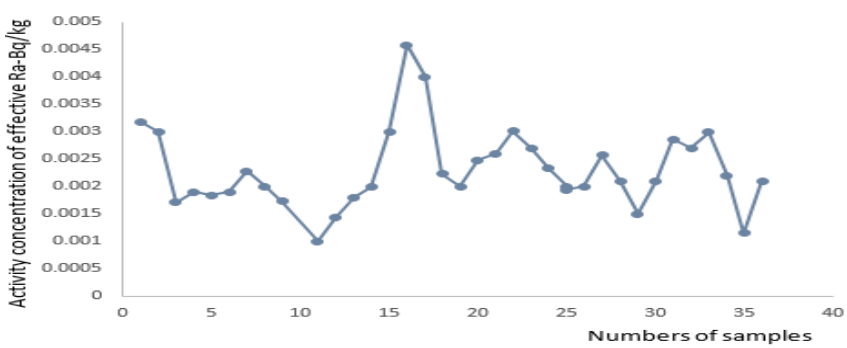

Fig. 7. Distribution of activity concentration of effective Ra (Bq/kg) in the studied samples.

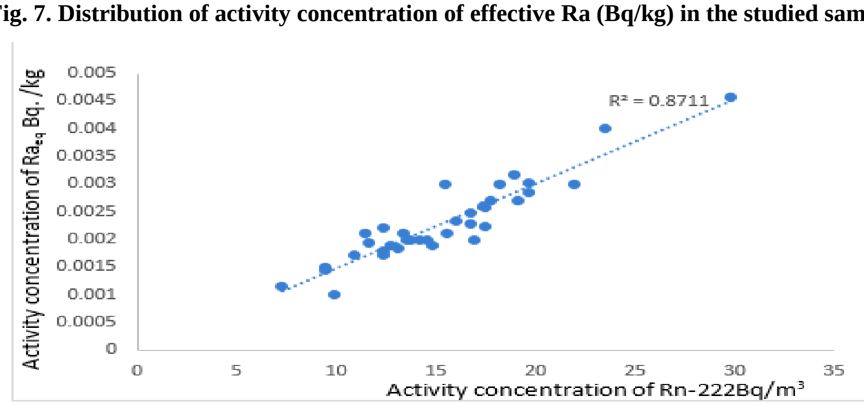

Fig. 8. Scatter plot showing the relation between Rn-222 and Raeff in the studied samples.

Table 2. Comparison between levels of radon concentrations recorded or estimated in many locations worldwide.

Location	^{222}Rn in Bq/m^3	Reference
Pakistan	376	Munza *et al.*, (2008)a
Turkey	3.4 – 138	Muslim *et al.*, (2011)a
Southern Lebanon	1774.291	Kobaissi *et al.*, (2008)a
Baghdad	7. 11	Saeed (1998)a
Central and Northern Iraq	33-100	Al-Ani (2000)a
Southern Iraq, Karmat Bani Said	1146.227	Mahsur (2009)a
Kut Eastern Iraq	583.594	Jabar (2001)a
Nasiriayh	1386.236	Kadhim (2014)
Ras Tanurah/Saudi Arabia	120	Al-Shari *et al.*, (2017)
Khor Abdullah/Iraq	606	Jaber *et al.*, (2015).
Marine sediments Iraq	288	Munaf *et al.*, (2018)
Standard	800	WHO
Ktibban- Basrah /Iraq	15	current study

4. Conclusion

The radon concentration values obtained from the present study and effective radium concentration showed that they are within the safe and universally permissible limits. They are safe, when their host sediments are used for building materials and any other applications associated with them. The values obtained for the exhalation values per unit volume and unit area also show that they are within the internationally accepted limits and there is no danger in their use. There is a very good correlation between the values of effective radium and the concentration of radon gas. These results help us complete the radiological map of the city of Basrah and its environs.

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تقدير غاز الرادون المنطلق من نهر كتبان شمال مدينة البصرة باستخدام CR-39

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المستخلص. في هذا العمل، تم استخدام تقنية العلبة المغلقة لتقدير محتوى الرادون والراديوم في العينات الصلبة التي تم جمعها من نهر كتبان، شمال مدينة البصرة. كان تركيز الرادون في العينات الصلبة المدروسة بين ٩,٤٦±٢,٢٩ $Bq.m^{-3}$ إلى ٢٩,٨٣ ± ٤,٨١ $Bq.m^{-3}$، بحيث يمكن أن يكون تباين الراديوم الفعال حوالي ٠,٠٠١ $Bq.kg^{-1}$ إلى ٠,٠٠٤٥٧١ $Bq.kg^{-1}$ لأنه كان مسؤولاً عن انبعاث غاز الرادون في الهواء. وتعتبر هذه القيم قيماً مقبولة عند المقارنة على مستوى العالم والدول المجاورة. التدفق والزفير لكل وحدة مساحة ولكل وحدة كتلة مرتبة بين ٠,١٣ $Bq\ m^{-2}\ h^{-1}$ إلى ٠,٥٤ $Bq\ m^{-2}\ h^{-1}$ و٠,٠٠٣ $Bq\ m^{-2}\ h^{-1}$ إلى ٠,٠١٥ $Bq\ m^{-2}\ h^{-1}$ على التوالي. هذه القيم أيضًا أقل من الحد العالمي المُبلغ عنه. قد يشير هذا إلى أنه من المحتمل أن يكون استخدام هذه الرواسب في مواد البناء والاستخدامات الأخرى آمنًا.

الكلمات المفتاحية: تركيز الرادون، SSNTDs، الراديوم الفعال.

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Growth, Feed, and Food Habits of *Saurida tumbil* (Bloch, 1795) in Jizan Fisheries, Saudi Arabia

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Abstract. The current study provides the latest scientific evaluation on growth and food habits of *Saurida tumbil* in Jizan fisheries. Monthly samples were collected from September 2021 to April 2022, with a total of 343 individuals. Fish scales were used for age determination and back-calculation of fish lengths at different ages to estimate growth rates and von Bertalanffy growth parameters. Several food analyses were carried out to describe the food habits of this species. Results showed that *Saurida tumbil* is categorized as carnivorous fish. Terapon (*Terapon* sp.) and anchovy (*Encrasicholina* sp.) were observed mostly in the stomach followed by sardinella (*Sardinella* sp.), squid (Loliginidae), and berber ponyfish (*Leiognathus berbis*). Vacuity index (VI) analysis showed that *Saurida tumbil* is categorised as middle alimentative regularly regarding the food habits and stomach fullness. The value of GaSI was 3.08 in average. The total Length – gutted weight relationship showed that *Saurida tumbil* is isometric in dimensional growth and can be described based on the power function. $W_{gutted} = 0.0067\ TL^{3.014}$ The average back-calculated lengths at different ages were 18.5, 27.0, 32.4 and 37.4 cm, respectively. The von Bertalanffy growth parameters were found to be: the asymptotic length $L_{\infty} = 50.38$ cm, growth constant K= 0.30 per year. The hypothetical age at zero length $t_0 = -0.48$ year. The growth in length performance index (Φ') was 2.88

Keywords: Asymptotic length; greater lizardfish; red sea; food preferences; compound index.

1. Introduction

In Saudi Arabia, the Red Sea coast of Jizan is an ideal fishing ground for trawling (Fig. 1). It has broad continental shelves with muddy and sandy bottom which is convenient for bottom trawlers. It exists along the eastern Red Sea coastal area with water depths ranging from 20-60 m. Most of catches consist of demersal fishes and penaeid shrimps (Bogorodsky et al., 2014).

The greater lizardfish *Saurida tumbil* (Bloch, 1795) is one of the demersal fishes which are commonly utilised there. It is widely distributed in the Indo-West Pacific region from Red Sea to Southeast Asia and Australia (Fischer & Bianchi, 1984; Jaiswar *et al*., 2003). Unfortunately, the exploitation of greater lizardfish may affect its biological activities, such as food habits and fish growth, due to the disturbance on natural condition, such as food availability and population size (Hart & Reynolds, 2002).

The assessment of threat level status on *S. tumbil* has attracted little concern by International Union for Conservation of Nature (IUCN, 2016). It has been categorised as not being a focus of species conservation. It means that the exploitation can be further performed in the future. However, Morgan (2006) and Ye (2011) stated that the fisheries resources in Jizan waters have been fully or already over-exploited. Scientific and continuous evaluation must be conducted to deliver the updated information.

Fisheries biology aspects of *S. tumbil* have been studied by many authors at different localities (Bakhsh, 1996; Jaiswar *et al*., 2003; Fofandi, 2011; Kalhoro *et al*., 2015; Najmudeen *et al*., 2015; Gabr & Mal, 2017). Nevertheless, there are only two studies on greater lizardfish in the Red Sea. The first one followed the reproductive biology of this species in the Jizan Region (Bakhsh, 1996), while the second one investigated the growth and stock assessment of this in Jizan fisheries (Gabr & Mal, 2017). The aim of the current study was to re-evaluate the growth and food habits of *S. tumbil* in Jizan fisheries.

2. Materials and Methods

Samples of *S. tumbil* were collected monthly from September 2021 to April 2022 from Jeddah central fish market where most of the caught fish from Jizan fisheries (Fig. 1) is being sold. The samples were transported in ice boxes directly to the laboratory for subsequent analysis. Fish samples were measured: total length TL (cm) and weight TW (g) by using measuring board to the nearest 0.1 cm and digital balance to nearest 0.1 g. Fish scales were collected and stored in Eppendorf tubes containing water (Gabr, 2015; Mostarda *et al*., 2016). Sea surface temperature data was collected from Aqua-MODIS satellite and extracted on SeaDAS software to describe general waters conditions. There are several methods and data analyses were used to achieve study objectives as follows:

2.1 Fish Growth

A total number of 343 fish specimens of *S. tumbil* (217 females and 126 males) were collected. The length-weight relationship of this species was calculated according to Le Cren (1951) with the following equation:

$$TW = aTL^b$$

Further t-test was performed to find the significant difference between value of b and 3 as described by Pauly (1984).

For age determination in fishes, scales were removed and cleaned in water, dried, and mounted between two microscope glass slides. Zoom Stereomicroscope fitted with digital video camera was used. AmScope software was used to capture and save pictures for further scale measurements, following Gabr & Mal (2017).

The relationship between the body length (TL) and scale radius (S) was calculated using the linear regression form:

$$L = c + dS$$

where c is the intercept and d is the slope. Both of values were used to calculate lengths at ages (back-calculated), based on the Body Proportional Hypothesis (BPH) method (Francis, 1990) as follows:

$$L_i = [(c + dS_i) / (c + dS)]\, TL$$

where L_i is the length at age of annulus i formation, S_i is the radius of the annulus i. The annual growth rates in length and in weight were determined from the average calculated lengths at ages. The growth of *S. tumbil* was measured using the following model (von Bertalanffy, 1938):

$$L_t = L_\infty\left[1 - exp^{-K\,(t-t_0)}\right]$$

The von Bertalanffy growth parameters, asymptotic length (L_∞) and the growth coefficient (K) were estimated according to Ford (1933) and (Walford, 1946), by fitting the method to the average back-calculated lengths-at-ages for males, females and sexes combined. The hypothetical age at zero length (t_0) was estimated using the following empirical equation suggested by (Pauly, (1980):

$$log_{10}(-t_0) = -0.3922 - 0.2752 \times log_{10}(L_\infty) - 1.038 \times log_{10}(K)$$

The growth in length performance index (phi-prime, Φ') for the species in Jizan fisheries was estimated by applying the estimated growth parameters (L_∞) and K in the following formula suggested by Pauly & Munro (1984):

$$\Phi' = log_{10}(K) + 2 \times log_{10}(L_\infty).$$

The life span (t_{max}) of *S. tumbil* in Jizan fisheries was estimated using the formula suggested by Taylor (1958) as follows:

$$t_{max} = t_0 + 3/K$$

2.2 Food Habits

The stomach contents of the fished were examined under a binocular microscope. The food materials were identified and weighted in an electronic balance, and its volume was estimated using displacement method. Vacuity index (VI), compound indices, and gastrosomatic index ($GaSI$) were determined to describe the food habits (Hynes, 1950; Pillay, 1952). Vacuity index (VI) was used to determine feeding intensity of each sample and the fish appetite for food. The degree of stomach fullness was classified as Full (IV), Three quarters full (III), One-half full (II), and A quarter full or empty (I). Full and Three quarters full stomachs indicate that the fish fed actively. VI was calculated using the equation of Euzen (1987).

$$VI = \frac{The\ number\ of\ empty\ stomachs}{total\ number\ of\ the\ stomachs\ examined} \times 100$$

The obtained value of VI indicated that fish is gluttonous when $0 \leq VI < 20$, comparatively gluttonous ($20 \leq VI < 40$), middle alimentary ($40 \leq VI < 60$), comparatively hypo alimentative ($60 \leq VI < 80$), and hypo alimentative ($80 \leq VI < 100$).

Occurrence index (O_i), number index (N_i), and volume index (V_i) were further estimated for the assessment of compound indices namely index of preponderance (I_i) and index of relative importance (IRI_i) (Natarajan & Jhingran, 1961; Pinkas, 1971; Chrisafi *et al*., 2007). Chipps & Garvey (2007) explained that the combination two or more indices produced one single index which is more reliable to inform the desirable properties of fish diet measures.

Occurrence index was assessed by the comparison between number of fish with food item i and number of fish with non-empty stomach. According to Euzen (1987), the occurrence index percentage of food item i can be divided into three categories. The prey eaten is dominant and the main diet when $O_i > 50$, secondary prey ($50 > O_i > 10$), eaten accidentally ($O_i < 10$).

Number index was estimated by the number of food item i divided by the total number of all food items. Meanwhile, volume index was valued by the volume of food item i divided by the total volume of all food items (Chipps & Garvey, 2007; Kuriakose *et al*., 2017). Index of preponderance was estimated by the following equation.

$$I_i = \frac{O_i V_i}{\sum_{i=1}^{Q} O_i V_i} \times 100$$

Index of relative importance was estimated using the following equation.

$$IRI_i = (\%N_i + \%V_i) \times \%O_i$$

Meanwhile the percentage of IRI was expressed by the following equation.

$$\%IRI_i = \frac{IRI_i}{\sum_{i=1}^{Q} IRI_i}$$

Gastrosomatic index ($GaSI$) is a relationship between weight of alimentary canal and weight of fish, which helps in determining the feeding condition in different months and seasons. Total weight of food of individual was divided by its body weight. GaSI were estimated as described by Biswas (1993).

$$GaSI = \frac{Total\ weight\ of\ stomach}{Bodyweight} \times 100$$

3. Results and Discussion

3.1 Water Temperature

The water temperature in Jizan waters (Fig. 2) was high in mid-September for summer and decreasing gradually to reach the lowest value in mid-March for winter. The water temperature in Jizan seems to be suitable for the growth of *S. tumbil*, as it was similar to those of 25-30°C recorded in other areas. According to Froese and Pauly (2022), the preferred temperature of *S. tumbil* is 18.4 - 29.1°C with mean of 27.9 °C.

3.2 Length-Weight Relationship

The total fish length ranged from 17.6 to 41.5 cm for females and from 18.7 to 38 cm for males. The total body weight ranged from 40 to 590 g and from 49 to 425 g for females and males, respectively. The relationship between the total length and total body weight of *S. tumbil* in Jizan fisheries is represented in Fig. 3 and described by the power equations as follows:

$$TW = 0.0053\, TL^{3.114} \quad (R^2 = 0.965, Total = 343)$$
$$TW = 0.0045\, TL^{3.162} \quad (R^2 = 0.956, Females = 217)$$
$$TW = 0.0054\, TL^{3.111} \quad (R^2 = 0.980, Males = 126)$$

T-test revealed that the b values, for females, and males were higher than 3 indicating a positive allometric growth of *S. tumbil* in Jizan fisheries (Table 6). P-value was 0.00043 for total fish, 0.00064 (females), and 0.00722 (males). The relationship between the total length (TL) and gutted weight (GT) could be described by the following power equations:

$$GW = 0.0067\, TL^{3.0144} \quad (R^2 = 0.977, Total = 343)$$
$$GW = 0.0060\, TL^{3.0470} \quad (R^2 = 0.969, Females = 217)$$
$$GW = 0.0078\, TL^{2.9670} \quad (R^2 = 0.982, Males = 126)$$

The b values obtained for the TL-GW relationship, for females, and males were not significantly different from value 3 confirming an isometric growth of *S. tumbil* in Jizan fisheries (Table 1). P-value was 0.581 for total fish, 0.193 for females, and 0.384 for males.

LWR analyses in the present study were compared to other results obtained by different authors at different localities (Table 3). Our results indicated similar somatic growth of *S. tumbil* to some of those observed in other areas, but they appeared different from other records. In the present study, the effect of stomach fullness and gonad weight (included in the total weight) may cause increasing b value (up to 3.114), indicating positive allometric growth, as reported in the same fishery (Gabr & Mal, 2017). By using the gutted fish weight, the value of b (3.014) indicated isometric growth, similar to the results of Bakhsh (1996) in the same fishery.

Isometric growth means the fish grows in height and width proportionally. Allometric positive means the growth of fish in height and width faster than the growth of fish in length. The fish generally has thick body. Meanwhile, the fish with allometric negative is elongated because the length grow faster than the weight or height (King, 2007; Kuriakose *et al*., 2017).

The variability in the b values for the *S. tumbil* at different localities (Table 2), might be related to some factors like water temperature, sex, and gonad maturity, available food items and stomach fullness degree, length type, and size range (Pitcher & Hart, 1982; Tesch, 1971).

3.3 Age Determination and Back-Calculations

Most previous studies used length frequency to estimate the age of *S. tumbil* (Jaiswar *et al.*, 2003; Kalhoro *et al*., 2015; Najmudeen *et al*., 2015; Rao, 1983). Gabr &

Mal (2017) used the whole otoliths for the first time to determine the age of this species in Jizan fisheries. In the present study, the scales were used to determine the age of *S. tumbil* in Jizan fisheries. The opaque and translucent (hyaline) bands of the scales (Fig. 4) were observed using reflected light on dark background. The opaque zones appeared as light zones and the translucent zones appeared as dark zones. Individual ages were estimated using the count of each pair of opaque and translucent bands (annulus) as annual time scale. Similar to Gabr & Mal (2017), the annual time scale was assigned for each pair of alternative opaque and translucent bands (annulus) on the scales of this species. The number of annuli formed on the scales was counted and the age (in years) could be assigned to each specimen. Four age groups (I^+ - IV^+) were determined for both females and males in the current study.

The opaque bands in the current study were thicker than the translucent bands indicating the history of the fish age over time. Green *et al*. (2009) proposed that the opaque band corresponds to fast somatic growth due to high food availability, intense feeding activity, high water temperature, and favorable environmental conditions in spring and early summer. Meanwhile, Carbonara & Follesa (2019) proposed that the translucent band was coincided with slow somatic growth at low food availability, stressful environmental conditions, and spawning season during autumn and winter. Bakhsh (1994) stated that the spawning of *S. tumbil* in Jizan fisheries occurred in winter season, confirming the conclusion reported by Gabr & Mal (2017) that stated the completion for each pair of alternative opaque and translucent bands occurred in the winter or early spring.

The relationship between total fish length (cm) and scale radius (mm) was fitted in linear regression (Fig. 5). It produced intercept (c) and slope (d) which were applied to back-calculation methods. The following equations represent the relationship between total length and scale radius for combined sexes, females, and males, respectively:

$$TL = 4.524S + 2.138 \quad R^2 = 0.976, n = 329$$
$$TL = 4.463S + 2.300 \quad R^2 = 0.974, n = 203$$
$$TL = 4.502S + 2.038 \quad R^2 = 0.967, n = 126$$

The length at the end of each year of life was back-calculated for each specimen using the body proportional hypothesis (BPH) formula for sexes combined as follows:

$$L_i = [(2.138 + 4.524S_i)/(2.138 + 4.524S)] \times TL$$

3.4 Growth in Length

The average back-calculated lengths at ages and the annual increment are given in Table 3 for combined sexes, females, and males, respectively. During the first year of life, the maximum growth in length and annual increment attained were: 18.6, 18.5, and 18.2 cm for combined sexes, females, and males, respectively. During the second year, the growth rate decreased to 8.5, 8.6, and 8.9 cm for both sexes, females, and males, respectively. The rate of length increase reached its minimum during the 4th year of life; 5.0, 5.0 and 5.3 cm for combined sexes, females, and males, respectively.

However, similar characteristic growth pattern and rates have been recorded for *S. tumbil* in other world regions, such as India and Pakistan waters (Rao, 1984; Najmudeen *et al*., 2015; Kalhoro *et al*., 2015). Gabr & Mal (2017) showed that *S. tumbil* reached 20.6 cm in the first year. The fish gained 7.5 cm of increment in the second year, 6.1 cm in the third year, and 4.3 cm in the fourth year. Hart & Reynolds (2002) asserted that growth in length can usually be modelled using an asymptotic curve. The increment of fish length is decreasing with increasing age which is similar to the results of the current study.

3.5 Growth Parameters

The von bertalanffy growth parameters for *S. tumbil* in Jizan fisheries were estimated based on the estimated growth rates, and the following von Bertalanffy Growth Functions (VBGF) were used to estimate the growth curves represented in Fig. 6.

For sexes combined,	$L_t = 50.38\left[1 - e^{-0.30\,(t\,+\,0.48)}\right]$
For females,	$L_t = 51.00\left[1 - e^{-0.30\,(t\,+\,0.48)}\right]$
For males,	$L_t = 49.59\left[1 - e^{-0.31\,(t\,+\,0.46)}\right]$

Table 4 also shows the growth parameters and performance index obtained in the present study compared to the results estimated for the same species by different authors at different localities.

The model illustrated the fish growth in length in accordance with fish ages (Fig. 6). It described the life history of *S. tumbil* in Jizan waters in specific period. However, the growth analysis results were different compared to the previous study by Gabr & Mal (2017). The asymptotic length (L_∞), 50.38 cm, in the present study was lower compared to the previous study with 52.98 cm. Kalhoro, *et al*. (2015) reported the lowest value (48.30 cm) from *S. tumbil* in Pakistan waters. Meanwhile, Najmudeen *et al*. (2015) discovered that the asymptotic length reached 51.70 cm in India waters. The value is the closest one to the current study results. However, the highest value was a long time ago recorded by Rao (1984) with the value of 63.70 cm with samples collected from India waters.

Growth constant (K) with the value of 0.30 per year was higher than the previous value of growth constant with 0.27 per year according to Gabr & Mal (2017). It indicated the rate of growing against time was faster than before. The parameter can also describe the vulnerability of the exploited fish. Musick (1999) and Cochrane & Garcia (2009) stated that the vulnerability is low when growth constant (K) is bigger than 0.3 in value. The results from Pakistan and India waters by Kalhoro, *et al*. (2015) and Najmudeen *et al*. (2015) respectively discovered the constants were also higher than 0.3, namely 0.32 and 0.40. Meanwhile, the lowest one was from study by Rao (1984) with 0.249 in India waters.

The other parameter of growth is t_{zero} (t_0). The estimated value (-0.48 year) in the present study was different compared to the result of the previous study by Gabr & Mal (2017) with the value of -0.84 year. The difference in fish growth study can occur due to many uncertain factors either biologically or ecologically. It is not the major issue since growth performance index for length (Φ') from current study (2.88) produced similar results with that (2.88) obtained by Gabr & Mal (2017). Pauly and Munro (1984) stated that growth performance index is the value to compare several fish growth performance from any locations in terms of fish length.

Life span estimation determined the longevity of *S. tumbil* in Jizan fisheries. It was estimated to be 9.5 years. According to the VBGF curve, the fish at this age had approximately total length of 47.86 cm which is 95% of the estimated L_∞ for this species. According to Taylor (1958), the fish is affected by temperature changes which determine the life span of the fish. However, fishing activities, waters properties, and food availability may also affect the life span of the fish. Thus, further evaluations regarding these parameters are encouraged to get more comprehensive estimation of fish maximum age and length.

3.6 Food Habits

Fourteen food items were observed in the fish stomach (Fig. 7), namely: (1) anchovy (*Encrasicholina* sp.), (2) herring (*Thryssa* sp.), (3) sardinella (*Sardinella* sp.), (4) terapon

(*Terapon* sp.), (5) Fourlined terapon (*Pelates quadrilineatus*), (6) berber ponyfish (*Leiognathus berbis*), (7) Klunzinger ponyfish (*Equulites klunzingeri*), (8) threadfin bream (*Nemipterus japonicus*), (9) goatfish (*Upeneus* sp.), (10) tounge sole (*Cynoglossus* sp.), (11) cardinalfish (Apogonidae), (12) shrimp (*Penaeus* sp.), (13) squid (Loliginidae), and (14) digested foods.

The frequency of each food item is illustrated in Table 6. The anchovy (*Encrasicholina* sp.) and terapon (*Terapon* sp.) displayed the highest frequency during the whole period of study (34 times each), with a maximum of 9 times for *Encrasicholina* sp. in October and 12 times for *Terapon* sp. in February. In addition, the squid (Loliginidae) was observed with 11 specimens during December. Digested food was observed 98 times.

According to the food items in the stomach of *S. tumbil*, it could be categorized as carnivorous fish. However, it may be also classified as piscivorous due to the dominance of fish items. Although Soofiani *et al*. (2006) reported similar observations, *S. tumbil* was suggested as a cannibal fish in Jizan (Bakhsh, 1996) and in India (Manojkumar & Pavithran, 2016).

The types of food that was found by Bakhsh (1996) be not found in the present study namely *Rastrelliger kanagurta*, *S. tumbil*, *S. undosquamis*, Carangidae, and Gobidae. The similar findings of foods from both studies were sardinella (*Sardinella* sp.), terapon (*Terapon* sp.), threadfin bream (*N. japonicus*), shrimp (*Penaeus* sp.), and squid (Loliginidae).

The possibility of encounter between *S. tumbil* and anchovy is high since the lizardfishes are categorised as demersal fish (Carpenter & Niem, 1999a) and anchovy (*Encrasicholina* sp.) is also found near to reef habitat. Meanwhile, terapon was consumed possibly because both of fishes shared same habitat in the ecosystem. Terapon is marine fish, but it also can reach reef and freshwater area. Meanwhile, *S. tumbil* is also stated as amphidromous fish that can reach freshwater area (Raza *et al*., 2022).

Squid (Loliginidae), berber ponyfish (*L. berbis*), and sardinella (*Sardinella* sp.) were found with moderate frequency. Squid and berber ponyfish are reasonable consumed by *S. tumbil* because both of organisms live in the same water depth range as the lizardfishes (20-60 m) (Froese and Pauly, 2022; Sommer *et al*., 1996). Sardinella as pelagic fish was preyed by *S. tumbil* because they are distributed in the same water characteristic, which is in neritic area where the waters are 10-70 m in depth (Carpenter & Niem, 1999a; Gell & Whittington, 2002). Furthermore, there were several organisms which was preyed by *S. tumbil* in small number. All of organisms live alongside *S. tumbil* in the environment with similar characteristic, such as depth range and ecosystem. However, the high abundance and availability of another type of foods made the probability of these organisms were consumed in small number by *S. tumbil* (Carpenter & Niem, 1998, 1999b, 2001; Kuriakose *et al*., 2017). Another possible reason might be related to the over-exploitation status of Jizan waters as stated by Morgan (2006) and Ye (2011). The low abundance of these organisms decreases the food availability for *S. tumbil*. In addition, the digested food in stomach of *S. tumbil* samples consisted of fish meats, fish bones, and fisheyes which emphasise *S. tumbil* as carnivorous fish.

Vacuity analysis showed the fullness condition of fish stomach. It is observed that there were 188 stomachs filled with foods and the rest (155 stomachs) were empty. Mean of vacuity indexes (VI) was 45.18 which meant the fish was middle alimentative averagely. The fully results are presented in Fig. 8.

Almost half of the total fish samples were observed to have empty stomach. However, the vacuity index fluctuated between comparatively gluttonous during late summer to early autumn and winter, middle alimentative during late autumn to early winter, comparatively hypo alimentative in early spring, and middle alimentative in late spring (Table 7). The relationship between stomach fullness and seasons for *S. tumbil* cannot be fully observed due to the fluctuation and diversity of result in food analysis (Mali *et al*., 2017; Manojkumar & Pavithran, 2016; Soofiani *et al*., 2006). Ecosystem capacity, interspecific interactions between organisms, and human activities impacts toward *S. tumbil* fisheries have crucial role in providing the relative and absolute foods to the species (Cochrane & Garcia, 2009; Kuriakose *et al*., 2017).

The percentage of occurrence index is given in Table 8. Anchovy (*Encrasicholina* sp.), terapon (*Terapon* sp.), squid (Loliginidae), and berber ponyfish (*L. berbis*) were categorised as secondary prey. Nevertheless, anchovy (*Encrasicholina* sp.) and terapon (*Terapon* sp.) might be the main diet as both of fishes produced the highest rank. Squid (Loliginidae) and berber ponyfish (*L. berbis*) furthermore were still considered as secondary prey. Meanwhile, the rest of foods were categorised as eaten accidentally with less than 10 of index value or significantly consumed in small numbers. For more explanation of *S. tumbil* food preference, the results of compound indices methods were shown in Table 9.

Index of preponderance and index of relative importance discovered terapon (*Terapon* sp.) as the most considered and important food consumed by *S. tumbil*. It was followed by anchovy (*Encrasicholina* sp.) and squid (Loliginidae). *Sardinella* sp. and berber ponyfish (*L. berbis*) were ranked in fourth and fifth places respectively. The rest of type food was accounted for less than 2.5% and together they only composed 4.44% for index of preponderance and 3.30% (IRI). The results were different according to Bakhsh (1996) which revealed the most abundant foods found in *S. tumbil* were lizard fish and sardines with 70% and 22% correspondingly. The current study showed that there were significant changes in the diet and prey availability of *S. tumbil* over time.

The means of GaSI was 3.08. The details of GaSI per month of sampling were presented in Fig. 9. Female and male fish tended to have average GaSI in September-October 2021 with 3.07-4.51 in value. GaSI of female fish increased in November 2021 (5.91) until reached the peak in December 2021 (6.24). Meanwhile, male fish was steady in average value in November 2021, but rose in December 2021 (6.92). GaSI of Both sexes were dropped in January 2022 (2.68-4.45) but rose back in February 2022 (6.20-6.81). GaSI of female fish kept rising until reached the second peak in March 2022 (9.38), while male fish was dropped to the average value (4.05). In April 2022, GaSI of both sexes had slightly similar value which was 6.06-6.10.

Female and male fish of *S. tumbil* tended to have high value in GaSI in period of spawning season[W71]. Female fish had high value in period of November-December and February-March. Meanwhile, male fish only reached the high value in December and February. Feeding intensity of *S. tumbil* tended to have relationship with the spawning season, but some studies (Metar *et al*., 2005; Norouzi *et al*., 2012) showed no correlations between spawning seasons and feeding intensity.

The present study suggested that *S. tumbil* in Jizan waters still had capability to fulfil its nutrition demands by predation. The vacuity index was high but tolerable. Meanwhile, the decent trend of GaSI value also has a chance to be increased by protecting the ecosystem to support the species and its prey ecologically and biologically to create the sustainability of food webs and food chains (Garcia, 2003; Kuriakose *et al*., 2017).

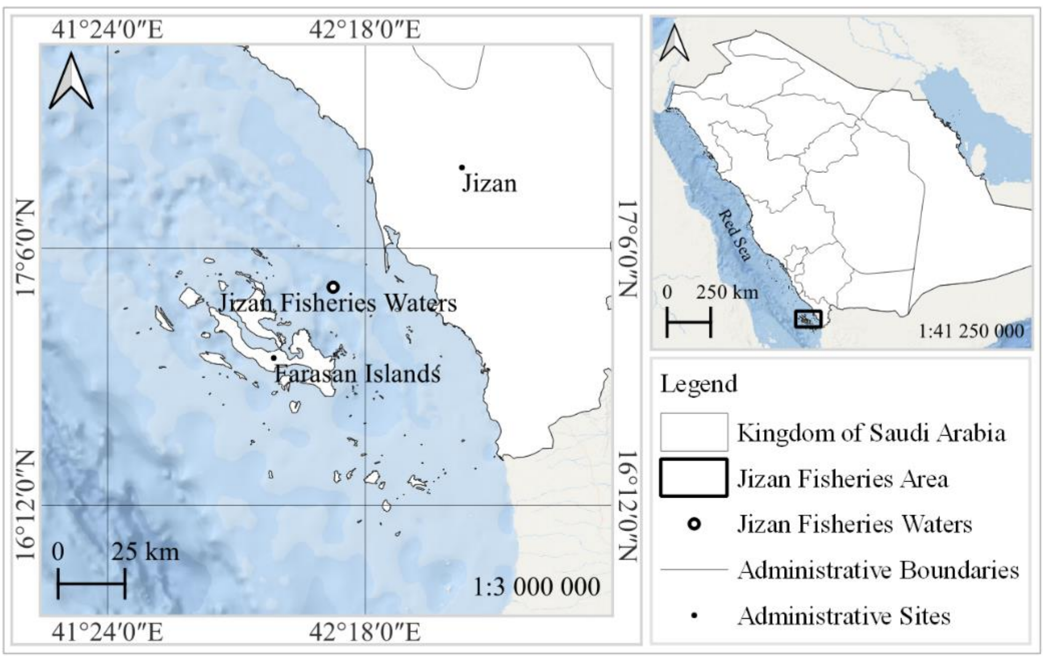

Fig. 1. Jizan fisheries location.

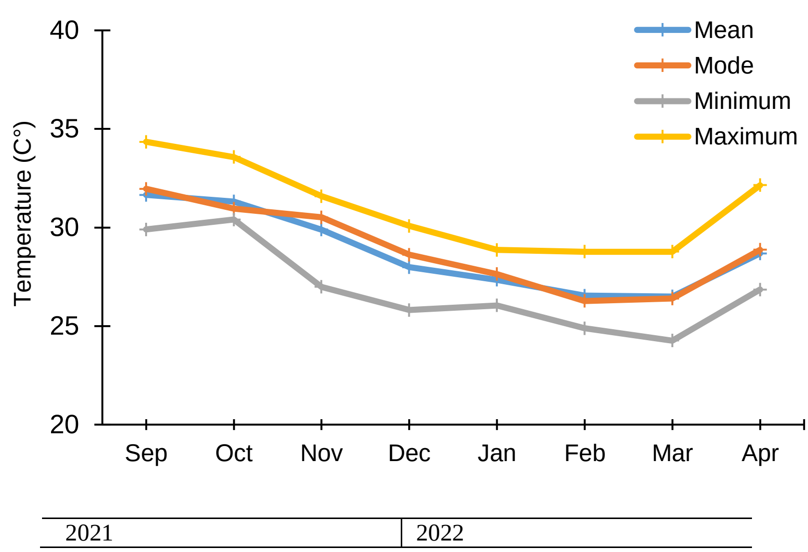

Fig. 2. Trend of temperature values in Jizan waters.

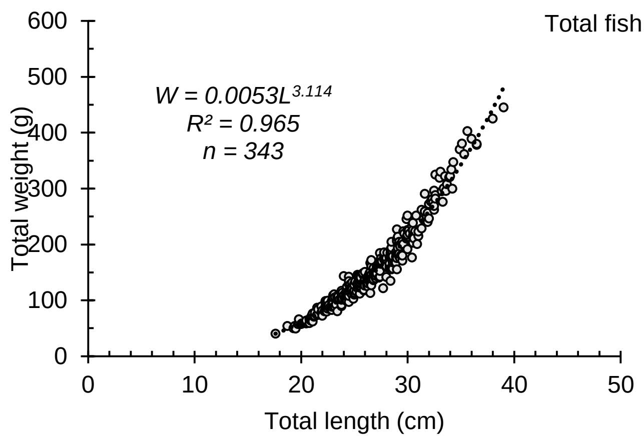

Fig. 3. Total Length-total weight relationship of *S. tumbil* collected from Jizan fisheries.

Table 1. Total length-total weight and total length-gutted weight relationship parameters of S. tumbil in Jizan fisheries.

Weight data	Category	Slope (b)	Intercept (a)	Correlation coefficient (R^2)	Somatic growth
Total weight (TW)	Total fish	3.114	0.0053	0.965	Allometric positive
	Female	3.162	0.0045	0.953	Allometric positive
	Male	3.111	0.0054	0.980	Allometric positive
Gutted fish weight (GW)	Total fish	3.014	0.0067	0.977	Isometric
	Female	3.047	0.0060	0.969	Isometric
	Male	2.967	0.0078	0.982	Isometric

Table 2. Length-weight relationship parameters of S. tumbil at different localities.

References	Location	b	a	R^2	Sex	Somatic growth	Length range	Weight type
Bakhsh (1994)	Jizan, Saudi Arabia	2.96	0.011	-	C	Isometric	12.0 – 33.0 (TL)	GW
Fofandi (2011)	India	3.25	0.0035	0.937	C	Allometric positive	15.2 – 39.9 (TL)	TW
Mohanchander *et al.* (2015)	India	3.066	7×10^{-5}	0.994	F	Allometric positive	13.0 – 43.0 (TL)	TW
		3.025	1.929	0.961	M	Allometric positive		TW
Kalhoro *et al.* (2015)	Pakistan	2.931	0.011	0.976	C	Allometric negative	3.0 – 46.0 (FL)	TW
(Mirzaei *et al.*, 2015)	Iran	3.421	0.002	0.957	F	Allometric positive	16.2 – 55.5 (TL)	TW
		3.402	0.002	0.969	M	Allometric positive	18.1 – 44.0 (TL)	TW
(Wang *et al.*, 2012)	China	3.047	0.975	0.994	C	Isometric	5.5 – 35.0 (SL)	TW
Gabr & Mal (2017)	Jizan, Saudi Arabia	3.150	0.0056	0.98	C	Allometric positive	16.1 – 41.0 (TL)	TW
		3.104	0.0056	0.97	F	Allometric positive	19.6 – 41.0 (TL)	TW
		3.097	0.0048	0.94	M	Allometric positive	16.1 – 31.7 (TL)	TW
Present study (2022), with total weight data	Jizan, Saudi Arabia	3.114	0.0053	0.965	C	Allometric positive	17.6 – 41.5 (TL)	TW
		3.162	0.0045	0.953	F	Allometric positive	17.6 – 41.5 (TL)	TW
		3.111	0.0054	0.980	M	Allometric positive	18.7 – 38 (TL)	TW
Present study (2022), with gutted fish weight data	Jizan, Saudi Arabia	3.014	0.0067	0.977	C	Isometric	17-6 – 41.5 (TL)	GW
		3.047	0.0060	0.969	F	Isometric	17.6 – 41.5 (TL)	GW
		2.967	0.0078	0.982	M	Isometric	18.7 – 38 (TL)	GW

Notes: M = Males, F = Females, C = Combined sexes, TL = Total Length, SL = Standard length, FL = Fork Length.

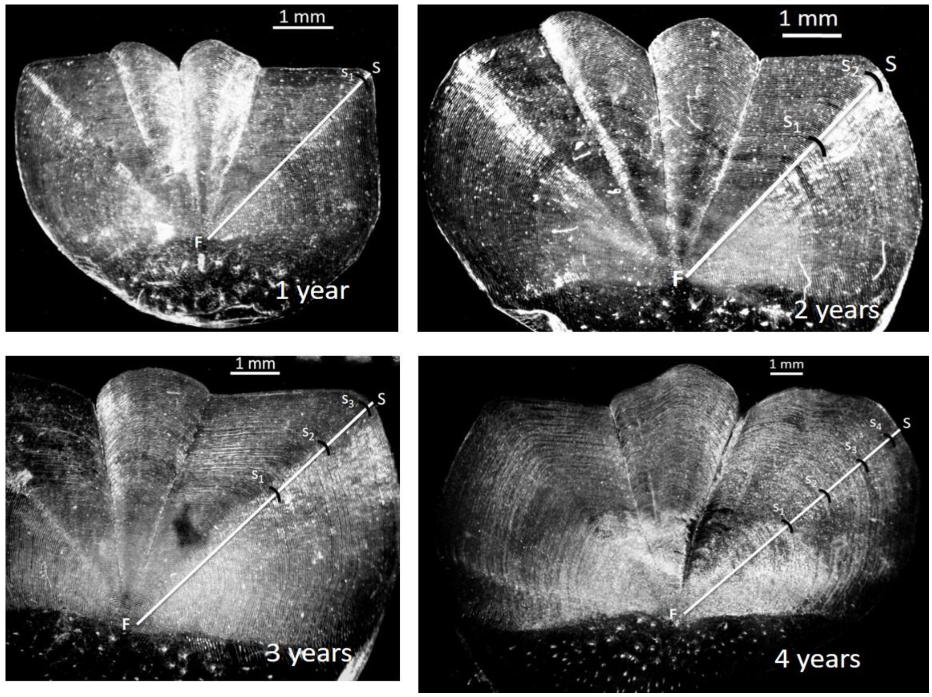

Fig. 4. The illustration of fish age determination based on scale observation of four age groups.

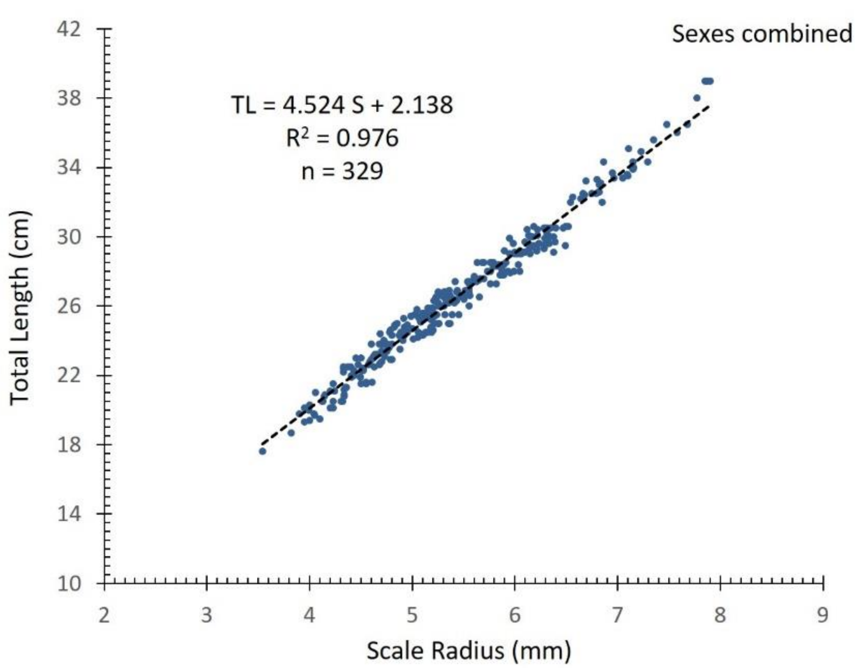

Fig. 5. The relationship between fish length (cm) and scale radius (mm) of total fish.

Table 3. The means of back-calculated total length at the end of year life.

Category	Details	Back-calculated total length at ages (cm)			
		Year I	Year II	Year III	Year IV
Sexes combined	Age group I+	18.6			
	Age group II+	18.4	26.7		
	Age group III+	18.2	26.6	32.3	
	Age group IV+	18.7	27.5	32.5	37.4
	Grand average	18.5	27.0	32.4	37.4
	Annual increment	18.5	8.5	5.4	5.0
Females	Age group I+	18.5			
	Age group II+	18.2	26.5		
	Age group III+	18.3	27.3	32.3	
	Age group IV+	19.0	27.6	32.9	37.6
	Grand average	18.5	27.1	32.6	37.6
	Annual increment	18.5	8.6	5.5	5.0
Males	Age group I+	18.2			
	Age group II+	17.8	26.7		
	Age group III+	17.9	26.9	32.2	
	Age group IV+	17.7	26.8	32.0	37.4
	Grand average	17.9	26.8	32.1	37.4
	Annual increment	17.9	8.9	5.3	5.3

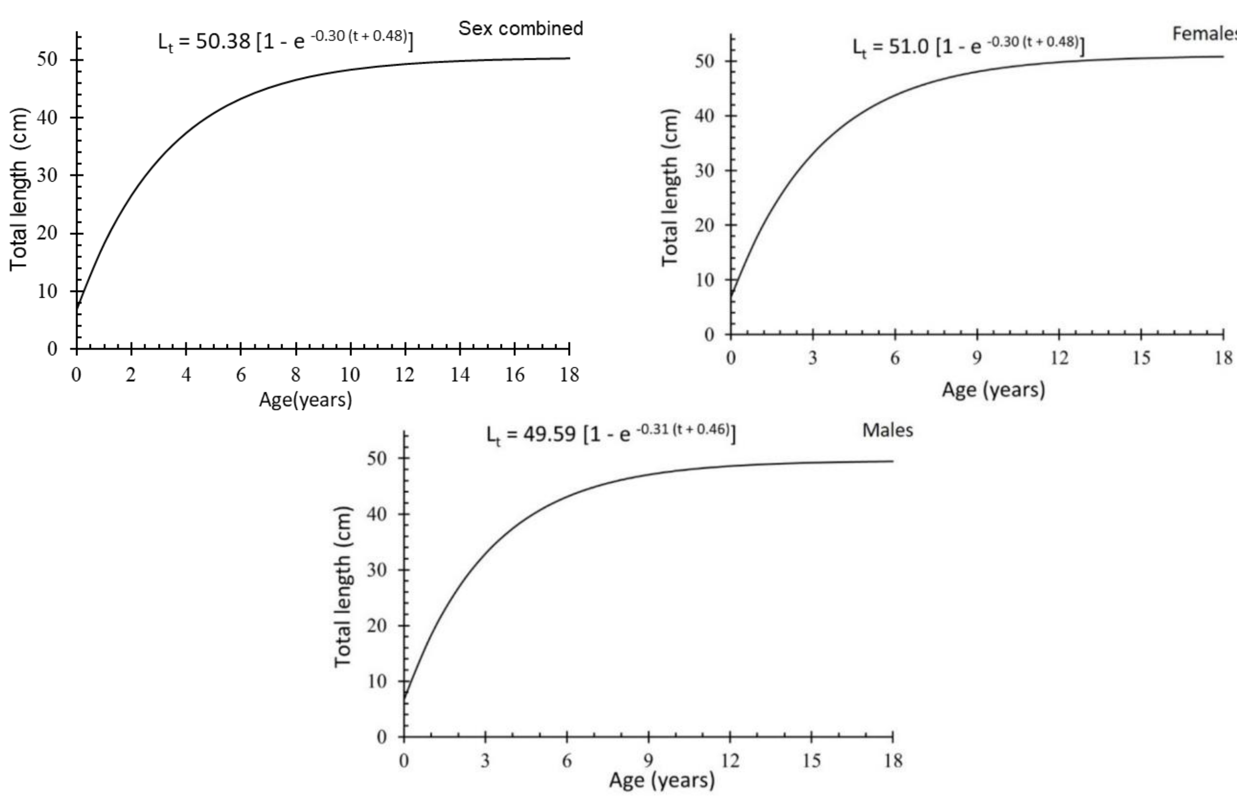

Fig. 6. von Bertalanffy growth curves of S. tumbil in Jizan fisheries.

Table 4. Growth parameters of S. tumbil estimated by different authors at different locations.

Author and Location	Age determination Method	Growth parameters			Growth performance Φ'
		K	L_∞	t_0	
Present study, Jizan, Saudi Arabia	Scale-based (Total Length)	0.30	50.38	-0.48	2.88
Gabr & Mal (2017), Jizan, Saudi Arabia	Otolith-based (Total Length)	0.27	52.98	-0.837	2.88
Kalhoro, *et al*. (2015), Pakistan	Length-based (Fork Length)	0.32	48.30	-0.786	2.87
Najmudeen *et al*. (2015), India, Kerala	Length-based (Total Length)	0.40	51.70	-0.188	3.03
Rao (1984), India, Bay of Bengal	Length-based (Total Length)	0.249	63.70	-0.334	3.00

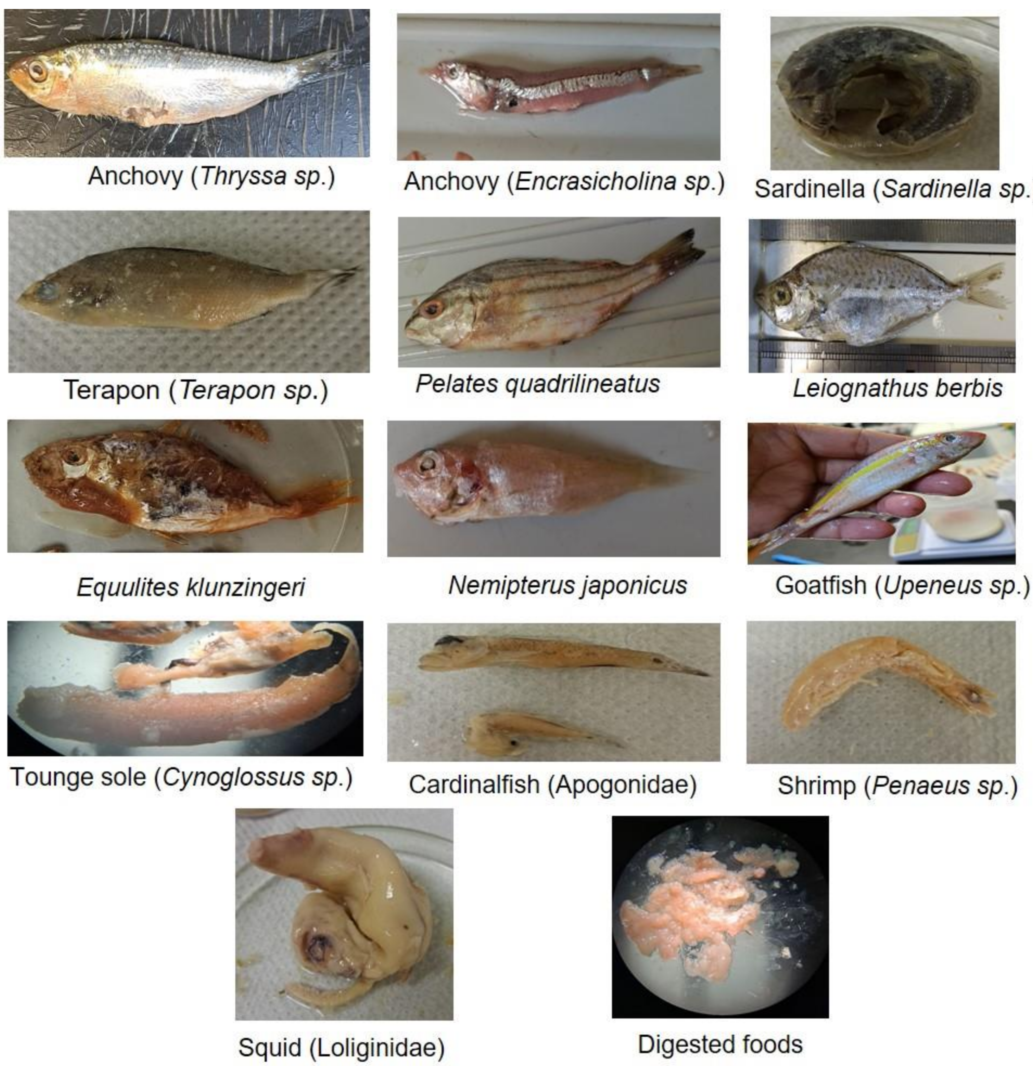

Fig. 7. Stomach contents of Saurida tumbil in Jizan fisheries.

Table 6. Types of foods and its frequency per month.

Type of food	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Freq.
Anchovy (*Encrasicholina* sp.)	3	9	0	7	5	8	1	1	34
Herring (*Thryssa* sp.)	0	0	1	0	0	2	0	0	3
Sardinella (*Sardinella* sp.)	0	0	0	0	1	6	0	2	9
Terapon (*Terapon* sp.)	0	1	4	4	5	12	4	4	34
Fourlined terapon (*P. quadrilineatus*)	0	0	1	0	3	0	1	1	6
Berber ponyfish (*L. berbis*)	2	1	0	0	1	2	4	0	10
Klunzinger ponyfish (*E. klunzingeri*)	0	0	1	0	0	0	1	0	2
Threadfin bream (*N. japonicus*)	0	0	1	0	0	0	1	0	2
Goatfish (*Upeneus* sp.)	0	0	0	1	0	1	0	0	2
Tounge sole (*Cynoglossus* sp.)	0	1	0	0	0	0	0	0	1
Cardinalfish (Apogonidae)	0	0	0	0	0	0	0	2	2
Shrimp (*Penaeus* sp.)	0	1	1	0	0	0	0	0	2
Squid (Loliginidae)	0	0	0	11	1	1	1	0	14
Digested food	17	18	26	14	7	10	3	3	98

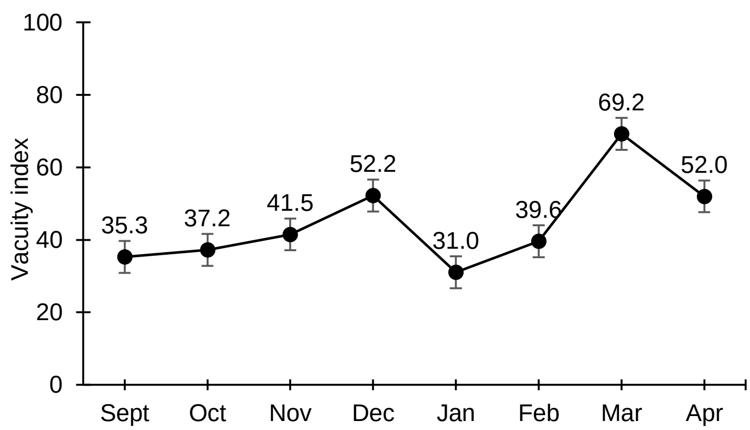

Fig. 8. Vacuity index per month.

Table 7. Stomach fullness description throughout study period regarding the season.

<table>
<tr><td colspan="6">2021</td><td colspan="5">2022</td></tr>
<tr><td colspan="2">Sep</td><td>Oct</td><td>Nov</td><td colspan="2">Dec</td><td>Jan</td><td>Feb</td><td colspan="2">Mar</td><td>Apr</td></tr>
<tr><td>Summer</td><td colspan="4">Autumn</td><td colspan="4">Winter</td><td colspan="2">Spring</td></tr>
<tr><td colspan="3">Comparatively gluttonous</td><td colspan="3">Middle alimentative</td><td colspan="2">Comparatively gluttonous</td><td colspan="2">Hypo alimentative</td><td>Middle alimentative</td></tr>
</table>

Table 8. The percentage of occurrence index of fish food habits analysis.

Type of food	% O_i	Rank	Category
Anchovy (*Encrasicholina* sp.)	34.34	1	Secondary prey
Herring (*Thryssa* sp.)	3.03	6	Eaten accidentally
Sardinella sp.	9.09	4	Eaten accidentally
Terapon (*Terapon* sp.)	34.34	1	Secondary prey
Fourlined terapon (*P. quadrilineatus*)	6.06	5	Eaten accidentally
Berber ponyfish (*L. berbis*)	10.10	3	Secondary prey
Klunzinger ponyfish (*E. klunzingeri*)	2.02	7	Eaten accidentally
Threadfin bream (*N. japonicus*)	2.02	7	Eaten accidentally
Goatfish (*Upeneus* sp.)	2.02	7	Eaten accidentally
Tounge sole (*Cynoglossus* sp.)	1.01	8	Eaten accidentally
Cardinalfish (Apogonidae)	2.02	7	Eaten accidentally
Shrimp (*Penaeus* sp.)	2.02	7	Eaten accidentally
Squid (Loliginidae)	14.14	2	Secondary prey
Digested foods	-	-	-

Table 9. The result of compound indices methods of food habits analysis with ranking in brackets.

Type of food	$\%O_i$	$\%N_i$	$\%V_i$	I_i	IRI_i	$\%IRI_i$
Anchovy (*Encrasicholina* sp.)	34.34	28.10	14.35	27.08 (2)	1457.76	35.39 (2)
Herring (*Thryssa* sp.)	3.03	2.48	10.84	1.81 (7)	40.35	0.98 (7)
Sardinella sp.	9.09	7.44	14.83	7.41 (4)	202.40	4.91 (4)
Terapon (*Terapon* sp.)	34.34	28.10	21.36	40.32 (1)	1698.52	41.23 (1)
Fourlined terapon (*P. quadrilineatus*)	6.06	4.96	6.57	2.19 (6)	69.88	1.70 (6)
Berber ponyfish (*L. berbis*)	10.10	8.26	4.53	2.51 (5)	129.23	3.14 (5)
Klunzinger ponyfish (*E. klunzingeri*)	2.02	1.65	0.38	0.04 (11)	4.11	0.10 (11)
Threadfin bream (*N. japonicus*)	2.02	1.65	0.49	0.05 (10)	4.33	0.11 (10)
Goatfish (*Upeneus* sp.)	2.02	1.65	1.76	0.20 (8)	6.89	0.17 (8)
Tounge sole (*Cynoglossus* sp.)	1.01	0.83	0.16	0.01 (12)	0.99	0.02 (12)
Cardinalfish (Apogonidae)	2.02	1.65	0.87	0.10 (9)	5.09	0.12 (9)
Shrimp (*Penaeus* sp.)	2.02	1.65	0.41	0.05 (10)	4.17	0.10 (11)
Squid (Loliginidae)	14.14	11.57	23.46	18.24 (3)	495.40	12.03 (3)
Total	122.22	100.00	100.00	100.00	4119.14	100.00

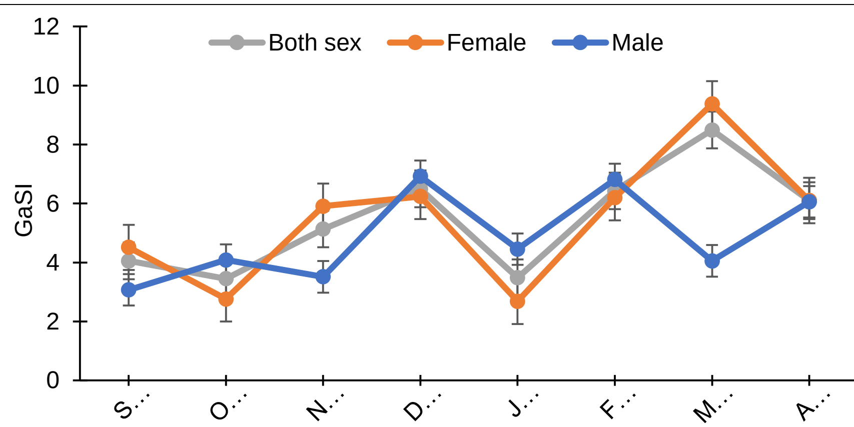

Fig. 9. Gastrosomatic index per month.

4. Conclusions

The present study showed that the growth of *S. tumbil* in Jizan fisheries is isometric. The average back-calculated lengths at age were 18.5, 27.0, 32.4 and 37.4 cm corresponding to the first, second, third and fourth year of life, respectively. The von Bertalanffy growth parameters were found to be: the asymptotic length L_∞ = 50.38 cm, growth constant K= 0.30 per year. The hypothetical age at zero length t_0 = -0.48 year. The growth in length performance index (Φ') was 2.88. The maximum Life span of *S. tumbil* in Jizan fisheries was estimated to be 9.5 years. This species was categorized as carnivorous fish which was indicated by the types of food items found in the stomach namely, fish, mollusc, and crustacean. Terapon (*Terapon* sp.) and anchovy (*Encrasicholina* sp.) were observed mostly in the stomach followed by sardinella (*Sardinella* sp.), squid (Loliginidae), and berber ponyfish (*L. berbis*). Vacuity index (*VI*) analysis showed *S. tumbil* was categorised as middle alimentative regularly regarding the food habit according to stomach fullness. Value of GaSI was 3.08 in average.

Acknowledgments

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النمو والعلف والعادات الغذائية لسمكة *Saurida tumbil* (بلوخ، ١٧٩٥) في مصايد جيزان، المملكة العربية السعودية

سوجنج هارتونو، و **ميسر حامد أبو الريش،** و **محمد حسني جبر**

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المستخلص. تقدم الدراسة الحالية أحدث تقييم علمي للنمو والعادات الغذائية لأسماك المكرونة *Saurida tumbil* في مصايد جيزان. تم جمع عينات شهرية من سبتمبر ٢٠٢١ إلى أبريل ٢٠٢٢، بإجمالي ٣٤٣ سمكة. وتم استخدام قشور الأسماك لتحديد العمر والحساب الرجعى لأطوال الأسماك عند الاعمار المختلفة لتقدير معدلات النمو ومعايير نمو فون برتالانفي. تم إجراء العديد من التحليلات الغذائية لوصف العادات الغذائية لهذا النوع. وأظهرت النتائج أن *Saurida tumbil* تصنف على أنها أسماك آكلة اللحوم. ولوحظ أن أسماك التيرابون (*Terapon* sp.) والأنشوجة (*Encrasicholina* sp.) تتواجد في غالبية الأمعاء وتليها أسماك السردين (*Sardinella* sp.) والحبار (Loliginidae) وأسماك نعومة الفكوك (*Leiognathus berbis*). أظهر تحليل مؤشر الفراغ (VI) أن *Saurida tumbil* يصنف على أنه غذائي متوسط بانتظام فيما يتعلق بالعادات الغذائية وامتلاء المعدة. وكانت قيمة مؤشر الاحشاء الجسدي GaSI هى 3.08 في المتوسط. وأظهرت علاقة الطول الكلي – الوزن بدون الاحشاء أن نمو اسماك المكرونة *Saurida tumbil* هو نمو مثالي ويمكن وصفه بناء على معادلة القوة: $W_{gutted} = 0.0067\ TL^{3.014}$، وكان متوسط الأطوال المحسوبة عند الأعمار المختلفة هو ١٨,٥ و٢٧,٠ و٣٢,٤ و٣٧,٤ سم على التوالي. تم حساب معاملات النمو لفون برتالانفي، وكانت: الطول الاقصى $L_\infty = 50.38$ سم، وثابت النمو $K = 0.30$ في السنة. والعمر الافتراضي عند الطول صفر $t_0 = -0.48$ سنة. وكان مؤشر النمو في الطول (Φ') = 2.88.

الكلمات المفتاحية: الطول المقارب سمكة سحلية أكبر، البحر الأحمر، أذواقهم الغذائية، مؤشر مركب.