

ORIGINAL ARTICLE

Decadal status of sardine fishery in Oman: Contribution of the Omani-Indian Oil sardine *Sardinella longiceps* Valenciennes, 1847 (Teleostei: Clupeidae)

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Abstract

Fisheries is one of the main divisions in the Omani economy, providing about 54968 direct employment in 2020, and the costal sardine fisheries make a major contribution to the country's income. In this study, the fluctuations in abundance of the sardines especially Indian oil sardine *Sardinella longiceps*, a tropical small pelagic clupeid fish, was investigated during the years 1995 to 2020 in Oman. The results reveal that Oman fisheries including sardine stocks show fluctuations during the last 26 years (1995-2020), showing two periods of recession (1995-2011) and upturn (2012-2020). In the second period, small pelagic landings, mainly sardines, increased dramatically in Oman starting from 2012 (about 70,697 t), reaching a peak of 530,022 t in 2020. This reveals that the Omani small pelagics were heavily targeted during the last 10 years. However, so far, the small pelagic fisheries are not managed and there is a need for an urgent conservation and recovery plan before it is too late. In India, sardine landings were reported as high as a half million tones before it dropped to less than 55 thousand tons only in 2012, a scenario that could repeat itself in Oman in near future. To overcome this, sardine landings must be maintained according to the identified sardine's biomass per given region, fishing effort must be carefully controlled and defined via a licensing system, sardine fishery must be closed every three years for at least one year to allow a fully recovery sardine stocks, reproductive biology, population dynamics and food and feeding habits of sardines should be studied in details and population size of jellyfishes which are larval and young fish predators of sardines should be monitored.

Keywords: Marine fisheries, Clupeid fishes, Fish production fluctuation, Omani economy.

INTRODUCTION

Global fish production is estimated to have reached about 179 million tonnes in 2018 of which, 156 million tonnes were used for human consumption, equivalent to an estimated annual supply of 20.5 kg per capita (FAO 2020). The remaining 22 million tonnes were destined for non-food uses, mainly to produce fishmeal and fish oil. China has remained a major fish producer, accounting for 35 percent of global fish production in 2018. Excluding China, a significant share of production in 2018 came from Asia (34 percent), followed by the Americas (14%), Europe (10%), Africa (7 %) and Oceania (1%). Total fish production has seen important increases in all the continents in the last few decades, except Europe and the Americas whereas it has almost doubled during the last 20 years in Africa and Asia (FAO 2020).

Fisheries is one of the main divisions in the Omani economy, providing about 54968 direct employment

in 2020 and the costal sardine fisheries make a major contribution to the country's income. Among different species of sardines, the Omani-Indian Oil sardine *Sardinella longiceps* Valenciennes, 1847 is considered to be the most abundant single fish species along the Omani coast. *Sardinella longiceps* is a coastal, pelagic, schooling and strongly migratory marine clupeid fish. It is widely distributed in Red Sea, western Indian Ocean: East Africa, Somalia, Gulf of Aden, Socotra and Persian Gulf east to India (Fricke et al. 2021). The Omani Indian Oil sardine feeds mainly on phytoplankton (especially diatoms), both as juveniles and adults, but also on zooplankton, especially copepods by the juveniles (see Sommer et al. 1996; Purusothaman et al. 2014). It breeds once a year, the spawners arriving off western coasts of India in June-July when temperatures and salinity are low during the southwest monsoon months (occurs at temperatures of 22.0-28.0°C); extended spawning season, but most

intense in August-September (Nair 1973; Whitehead 1985). In Oman, mature and spent gonads are found from July to September and in January to February, indicating presence of two peaks of spawning periods, although, the periodicity differs slightly in different years (Zaki et al. 2021).

The fish feeds primarily on diatoms, while dinoflagellates, copepods and fish eggs are also found as minor items (Zaki et al. 2021). The Indian Oil sardine is marketed fresh, dried and dried-salted, and it is also consumed in the forms of smoked and canned (Frimodt 1995). *Sardinella longiceps* is also made into fish meal and fish balls.

Sardinella longiceps is a forage clupeid fish comes under the group 'herring, anchovies and sardine, (HAS) which contributes to 18.6% (15.3 million tons) of the global marine capture fishery production (FAO 2016). Among the five countries which harvest oil sardine (0.572 million tons) from their coastal waters, Oman with 63,439 t, gets the second rank in the world after India (65%, 376,189 t) (FAO, 2016). In Oman, *S. longiceps* is targeted by small scale traditional fishermen up to 50m using traditional gears including beach seines and modified gillnets. Contribution of the small pelagic fishes, mainly sardines, varied from 21.4% to 51.3% between 1995 and 2009; and 30 to 35% during the period 2002-2009 (GoSO 2003; 2009). Total sardines catch contributes up to 35% to the total fish Omani fish landings in 2009 (Al-Anbouri et al. 2011). There are several clupeid species within the total sardines catch composition, however, the total catch is mainly comprised by *S. longiceps* and in lesser extent by the goldstripe sardinella, *Sardinella gibbosa* (Bleeker 1849) and Sind sardine, *S. sindensis* (Day, 1878). The Indian oil sardine catches contribute to about 80% of the total sardine's catches (Al-Abdessaalam 1995; Zaki et al. 2013). However, like other sardine landings around the world, the Omani sardine landings are subject to fluctuation due to environmental changes and market demands (Ministry stats, Krishnakumar et al. 2008; GoSO 2009). These up and down catch trends are well known in sardine fisheries around the world regardless to the reasons given (Al-Jufaili 2006).

In recent years small pelagics mainly sardines were targeted by the local coastal fishermen due to the increase in the demand by the fish meal industry. The fish production has tripled from 2015 to 2020 from 275,000 mt to 840,000 mt with an annual growth rate of 24.6%, and with it the values have doubled as well. As a result, the fishery sector contribution to the Sultanate's GDP has increased as well to reach 5.5% when compared to 2018 (MAF 2020). This upturn in the sardine industry led the total sardines' landings increase almost ten times within the last 9 years. It is clear that, the number of fishermen targeting the sardines also increased to cover the demanded quantities by the industry. As a result, total sardines quantities exported has increased as well to cover the fish meal industry demand in the international market. Hence, this study aims to provide data on the sardine's landings, values, local and export prices per ton, quantities of sardines exported over the years. The study concludes with recommendations on the management and development of the sardine fishery along the Omani coast.

MATERIAL AND METHODS

Data used for the analysis were obtained from the Ministry of the Agriculture and fisheries logbook for the last 26 years from 1995 to 2020. The landings statistics in the yearbook are divided into small pelagics, large pelagics, demersals, sharks and rays, and crustaceans. The current analysis uses only the finfish's stats, excluding sharks and rays. The fish stats in the logbook are not presented to species level, rather they are presented to fish group level. For example, sardines under small pelagic category, are given as total sardines, which includes mainly *Sardinella longiceps* data and other sardines e.g., *S. gibbosa* and *S. albella* among others (Al-Jufaili et al. 2010).

Sardine export quantities as well as their values and prices were compared over the years with the local quantities and prices per ton. The data were

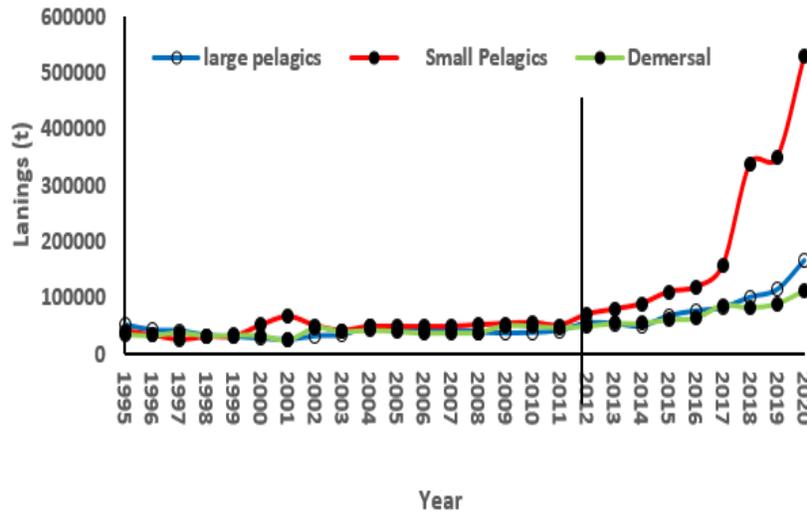


Fig.1. Omani fish groups landings over the years with an indication of the fisheries landings upturn starting 2012.

Table 1. Average percentage contribution of "Fish groups" to the total finfish landings and values per periods 1995-2011, 2012-2020, and 1995-2020.

	1995-2011		
	Demersal	Large Pelagics	Small pelagics
Landings	32	31	37
Values	35	43	23
	2012-2020		
	Demersal	Large Pelagics	Small pelagics
Landings	20	24	56
Values	30	48	22
	1995-2020		
	Demersal	Large Pelagics	Small pelagics
Landings	25	27	49
Values	32	46	22

analysed by Microsoft Excel 2019 where it is applicable based on the upturn and recession periods.

RESULTS

Landings and values: Fish groups landings were divided into the two periods, including 1995-2011 recession and upturn 2012-2020 periods. During the recession period (17 years), small pelagics, contributed 37 % to the average total Omani finfish fishery landings, which was the highest among other fisheries contributions.

Demersals and large pelagics contributed 32% and 31% respectively (Fig. 1). On the other hand, small pelagics contributed the minimum to the average total values (23%), compared to the large

pelagics (43%) and the demersal (34%) contributions (Table 1, Fig. 2).

During the upturn period 2012-2020 (9 years) small pelagics contributed 56% to the average total landings compared to 24 % and 20% large pelagics and demersal contributions, respectively (Fig. 1). Small pelagics, on the other hand, contributed the minimum in terms of values, 22% only, compared to 48% from the large pelagics and 30% from the demersals (Table 1, Fig. 2). During the overall period, 1995-2019 (26 years), small pelagics contributed the highest to the total average landings 49% followed by large pelagics and demersals, 27% and 25%, respectively. On the other hand, small pelagics contributed the minimum to the total average values, 22%, compared to 46% and 32% contribution from the large pelagics and demersal, respectively (Table 1).

The price per ton per group of fishes increased with positive slopes from 1995 to 2014 for the large pelagic fish group before it started to decrease after that dramatically until 2020. The same scenario was observed with the small pelagics where the maximum price per ton for the small pelagics was recorded in 2013, 436 OR before it started to decrease slowly until 2020. The price per ton for ton reached the minimum in 2020, 179 RO/ton. (Fig. 3). The prices per ton are opposite of the upturn period as they have decreasing for the past few years.

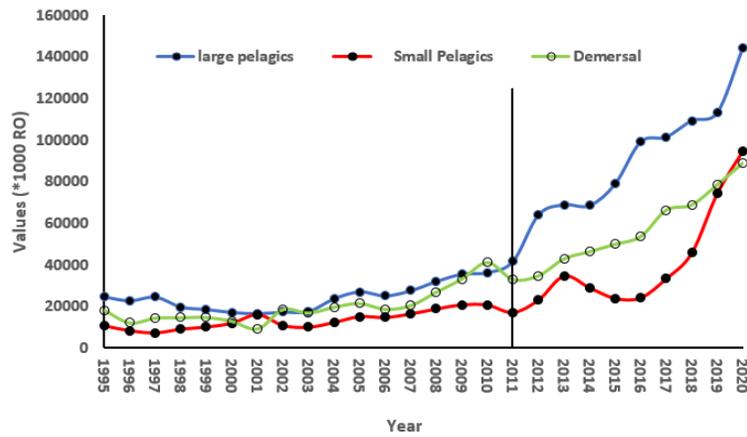


Fig.2. Omani fish groups values over the years with an indication of the fisheries landings upturn starting 2012.

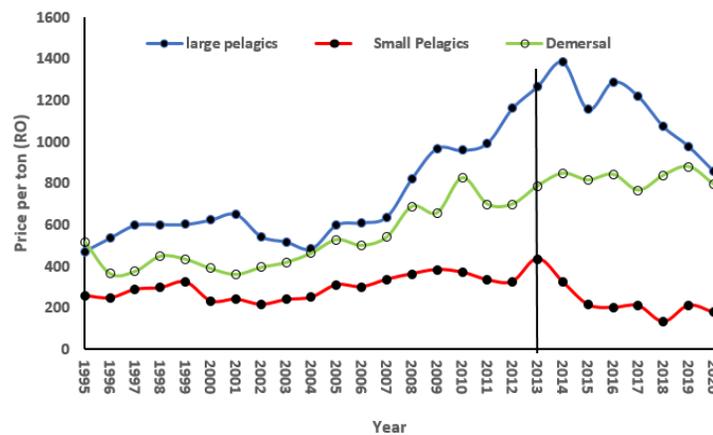


Fig.3. Omani fish group's price per ton in Omani Rials within the years 1995-2020, with an indication of price per ton collapse starting from 2013.

Total sardine landings. The sardine landings have experienced two eras so far according to the data analysed, a recession era of 17 years (1995-2011) and nine years of upturn or the boom era (2012-2020) (Fig. 4). During the upturn period, within nine years only, the total landings were 2.6 times the total landings recorded within the 17 years of the recession years. On the other hand, the average annual landings were 4.9 times more during the upturn period when compared to the recession average annual landings. The landings experienced a slight decrease in 2019 due to non-Omani's sardine fishermen layoff. However, more companies have entered the fishery and the landings went up again in 2020.

For the recession period 1995-2011 (17 years), the minimum registered catch was 16765 mt in 1997, while the highest was 58960 mt in 2001. The mean average landing for the 17 years was 32665 mt, and

the annual average catch increment was estimated to be in negative values (-137 mt). The highest annual increment was recorded in 2001 with a total increment of 18916 mt, while the lowest was recorded by -21029 mt in 2002. The total landings within this period were 555,312 mt (Fig. 5). For the upturn period 2012-2020 (9 years), sardine landings started to increase rapidly from 43549 mt in 2012 to almost 10 times folds in 2020 which recorded 430243 mt. The mean average landing during these nine years was estimated to be 161395 mt (4.9 times the recession period). The landings dropped in 2019 by -14147 mt. The total landings recorded so far within this period is 1,452,551 mt (Fig. 5). During the 1995-2011 period the Arabian Sea regions contributed 41% to the total average sardine landings in Oman versus 59% contribution from the Gulf of Oman regions. The contribution of the Arabian Sea regions increased to reach 90% during 2012-2020 up

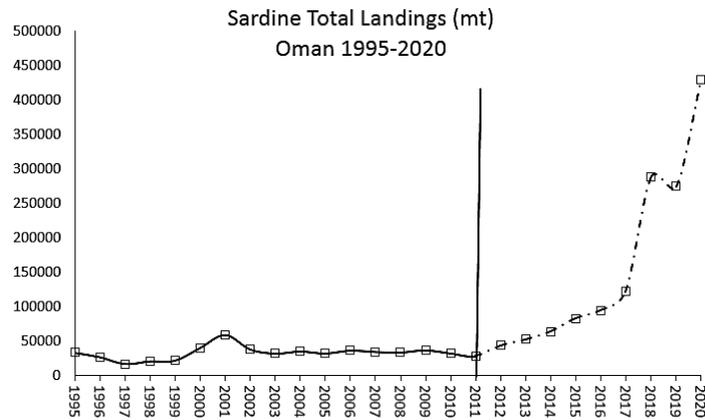


Fig.4. Total sardine landings in Oman divided into the recession period 1995-2011 and the up-turn period 2012-2020.

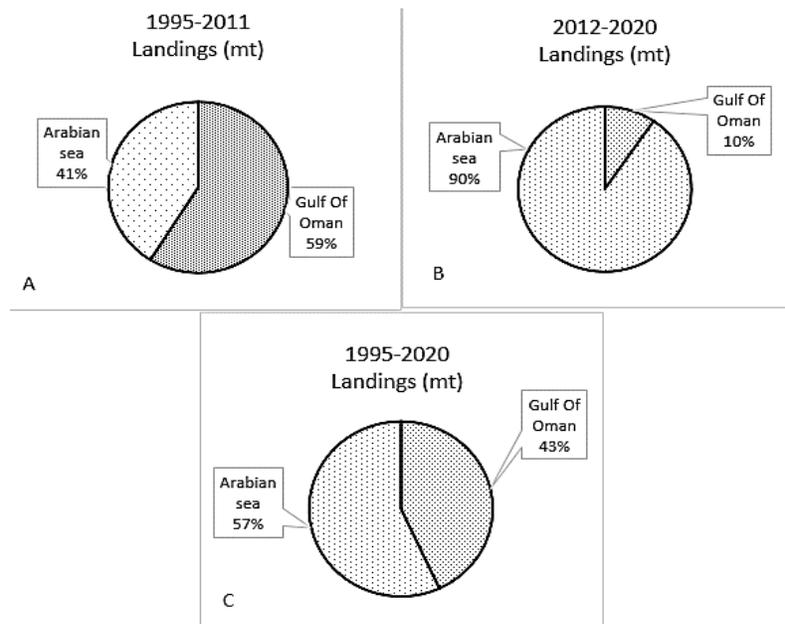


Fig.5. Sardine average (%) landings contributions Gulf of Oman regions (Musandam, Batinah, and Muscat) and per Arabian Sea regions (Sharqiyah, Wusta, and Dhofar) divided into three groups of years (A: 1995-2011, B: 2012-2020, and C: 1995-2020).

turn period. During the overall period 1995-2020, the contribution from the Arabian Sea regions is 57% versus 43% from the Gulf of Oman regions (Fig. 5). During the recession period (1995-2011), Muscat, Batinah, and Sharqiyah regions contributed the highest to the total sardine landings with values of 31%, 26% and 23% respectively. All regions had a negative average annual increment except Sharqiyah (7350 mt/yr) and Wusta (1963 mt/yr) regions. On the other hand, during the nine years upturn period (2012-2020), Wusta contributed 48% to the total sardine landings followed by Sharqiyah, 34%. Both regions contributed 82%. The percentage contribution for Batinah decreased from 26% to 6%,

while the Muscat contribution decreased the most from 31% to 2% only. Sharqiyah contribution increased from 22% to 34% while Wusta experienced the highest increase from 6% to 48%. The average annual catch increased by 7 times in Sharqiyah and increased by 40 times in Wusta (Table 2).

The average annual increment has increased in all regions, Wusta region recorded 12 times average annual increment within the upturn period 2012-2020 when compared to the rescission period 1988-2011 (Table 2). In overall and during the 25 years period (1995-2019), Wusta, Sharqiyah and Batinah regions were contributing the most into the sardine's

Table 2. Sardine landings statistics divided by the rescission period (1995-2011) and the upturn period (2012-2020). The stats included the average, minimum, maximum, and total landings contribution per region per era. Annual increment per region and the landings percentage contributions per regions are also provided.

Regions	Musandam	Batinah	Muscat	Sharqiya	Wusta	Dhofar
1995-2011 (16 years)						
Average	492(2%)	8478(26%)	10170(31%)	7350(22%)	1963(6%)	4212(13%)
Minimum	53	3908	1132	163	92	1809
Maximum	875	19181	17787	19607	4822	8468
Total	8372	144127	172897	124943	33364	71609
Annual incr.	-55	-625	-198	7350	1963	-351
2012-2020 (9years)						
Average	1282(1%)	9291(6%)	2873(2%)	54632(34%)	78129(48%)	15174(9%)
Minimum	515	2180	695	19413	13956	1398
Maximum	3310	23008	6168	140582	214357	42705
Total	11539	83616	25858	491691	703165	136569
Annual incr.	325	2079	560	13899	23282	4544
1995-2020(26 years)						
Average	750(1%)	10864(16%)	6545(10%)	18896(27%)	22500(33%)	9236(13%)
Minimum	53	2180	695	60	92	-4941
Maximum	3310	28832	17787	140582	214357	18675
Total	24736	358515	215996	623576	742506	42705
Annual incr.	3110	3658	4869	140424	214152	42705

landings. All the regions recorded an average annual increase excluding Batinah sardine landings which reported a decrease of 5257 tons per year.

Fishermen and boats. During 1995-2011, Musandam region registered a decrease in the number of fishermen and boats. On the other hand, all other regions have shown an annual increase in both number of fishermen and total boats. Rapid increment in number of fishermen and boats were observed in Dhofar region (387 and 127 per year respectively). The highest average number of fishermen and boats were recorded in Al Batinah region, 9998 and 4482 respectively (Table 3).

During 2012-2019, total number of fishermen and boats increased in all regions. However, the number of fishermen annually decreased in Al Wusta region per 74 fishermen per year. In addition, all regions experienced a faster rate of increasing in both Fishermen and number of boats. However, the number of boats has shown a slower decrease in Wusta when compared to the 1995-2011 period. Al Batinah, Sharqiyah and Dhofar recorded the highest average number of fishermen, 13507, 10442, and

10764 respectively. Rapid increment in number of fishermen and boats were observed in Sharqiyah region (440 and 282 per year respectively). During the whole period 1995-2019. The total number of fishermen in Musandam decreased annually by 3.5 fishermen per year. Al Batinah had the highest average number of fishermen and boats, 11121 and 4922 respectively. However, Dhofar had the highest annual increase in the number of fishermen reached up to 470 fishermen per year. While the Sharqiyah had the highest annual increment of 195 boats per year.

Total sardine values. During the rescission period (1995-2011), Batinah, Muscat, and Sharqiyah regions contributed the highest to the total sardine values, 34%, 32% and 20% respectively. All regions had a negative average annual increment except Sharqiyah and Wusta regions. On the other hand, during the nine years upturn period (2012-2020) Wusta contributed 45% to the total sardine values followed by Sharqiyah, 25%. Both regions contributed 70%. The percentage contribution for Batinah decreased from 34% to 13%, while the

Table 3. Fishermen and total boats per region stats during the 1995-2011 and 2012-2019 periods.

	Fishermen				Boats			
	1995-2011				2012-2019			
1995-2011	Average	Max	min	slope	Average	Max	min	slope
Musandam	3161	3780	2360	-13	1419	1587	1231	-3
Al-Batinah	9998	12036	8547	129	4482	4852	4080	22
Muscat	3867	4591	3022	79	1692	1960	1431	22
Al-Sharqiyah	6827	8865	5314	183	2764	4798	2081	123
Al-Wusta	3149	4522	2443	76	1578	3076	1271	61
Dhofar	4195	9853	2219	387	1982	3837	1410	127
2012-2019	Fishermen				Boats			
2012-2019	2012-2019				2012-2019			
2012-2019	Average	Max	min	slope	Average	Max	min	slope
Musandam	3108	3447	2706	102	1818	2118	1636	72
Al-Batinah	13507	14541	11943	344	5859	6319	5025	178
Muscat	5027	5538	4519	144	2270	2509	2033	56
Al-Sharqiyah	10442	11925	8192	440	5586	6721	4074	282
Al-Wusta	4208	5629	3411	-74	2865	3977	2220	12
Dhofar	10764	11394	10252	144	4512	4651	3983	66
Total	Fishermen				Boats			
1995-2019	1995-2019				1995-2019			
1995-2019	Average	Max	min	slope	Average	Max	min	slope
Musandam	3144	3780	2360	-3.5	1547	2118	1231	22
Al-Batinah	11121	14541	8547	235	4922	6319	4080	85
Muscat	4238	5538	3022	90	1877	2509	1431	39
Al-Sharqiyah	7984	11925	5314	261	3667	6721	2081	195
Al-Wusta	3488	5629	2443	77	1990	3977	1271	87
Dhofar	6297	11394	2219	470	2791	4651	1410	175

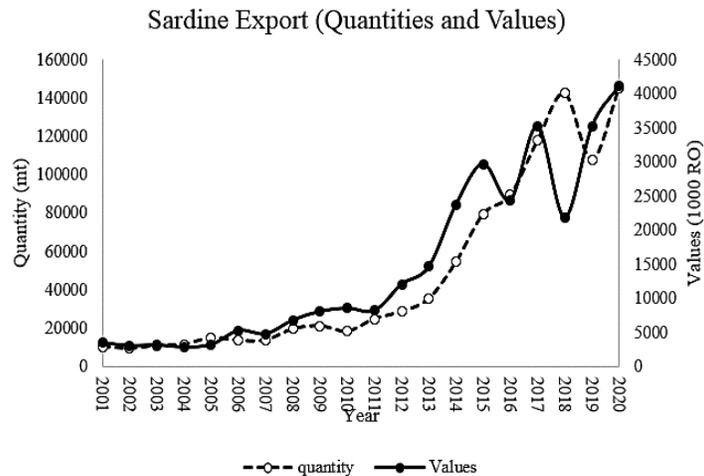


Fig.6. Total sardine export quantities and values over the years (2001-2019).

Muscat contribution decreased the most from 32% to 4% only. Sharqiyah contribution increased from 20% to 25% while Wusta experienced the highest increase from 5% to 45% (Table 4). The average annual increment has increased in all regions, Wusta region recorded 5 times average annual increment within the upturn period 2012-2020 when compared

to the rescission period 1988-2011 (Table 3). Overall and during the 26 years period (1995-2020), Wusta, Sharqiyah and Batinah regions are contributing the most into the sardine's landings.

Sardine local Price per ton. During 1995-2011 the highest sardine price per ton was reported in Batinah and the lowest was in Dhofar, 250 and 123 RO

Table 4. Sardine Values (*1000 RO) statistics divided by the recession period (1995-2011) and the upturn period (2012-2020). The stats included the average, minimum, maximum, and total landings contribution per region per era. Annual increment per region and the landings percentage contributions per regions are also provided.

	Musandam	Batinah	Muscat	Sharqiya	Wusta	Dhofar
1995-2011 (17 years)						
Average	98(2%)	2079(34%)	1951(32%)	1237(20%)	320(5%)	502(8%)
Minimum	11	1068	710	18	11	218
Maximum	312	6395	3189	4902	1112	1100
Total	1669	35349	33165	21029	5433	8530
Avg. Annual incr.	-3	-65	-155	1237	320	-12
2012-2020 (8 years)						
Average	307(2%)	2174(13%)	702(4%)	4247(25%)	7598(45%)	1712(10%)
Minimum	102	1050	417	1525	2772	253
Maximum	683	4706	1343	10030	18503	4988
Total	2766	19566	6322	38226	68383	15404
Avg. Annual incr.	68	299	70	908	1663	530
1995-2020 (26 years)						
average	171(2%)	2112(21%)	1519(15%)	2279(23%)	2839(28%)	921(9%)
Minimum	11	2112	417	18	11	921
Maximum	683	1050	3189	10030	18503	218
Total	4435	6395	39486	59255	73816	4988
Avg. Annual incr.	22	66	-74	393	640	183

respectively. On the other hand, the price per ton increased during the up-turn period (2012-2020) in all regions except in Sharqiyah (-72 RO) and Wusta (-13 RO). The highest increase was in Muscat by 90 RO per ton and the sharp decrease was recorded in Sharqiyah, -72RO per ton. Overall, the price per ton has decreased by 60RO/t from 192 Ro/t to 132 RO/t when the two periods 1995-2011 and 2012-2020 are compared (Table 5).

Sardine export. Continues export data were found during the period 2001-2020, which were used for the analysis. The data was divided into 2001-2011 (11 years) as the recession period and 2012-2020 (9 years) as the upturn period. During 2001-2011, small pelagics with sardines included annual export was the highest, 24185 mt per year, followed by the demersals and the large pelagics, 15991 mt and 12365 mt respectively. Without sardines the small pelagics contributed only 9001 mt annually and the sardines contributed 15184 mt. However, the average annual values from the small pelagics with

sardines were the lowest (10,245,000 RO) compared to the large pelagics (11,256,000 RO) and the demersals (13,003,000 RO). Without the sardines, average small pelagics contributed only 5,042,000 RO, while the sardines alone contributed 5,203,000 RO annually (Table 6).

During the upturn period, 2012-2020, the small pelagic with the sardines included average annual export increased to 105613 mt and the demersals increased to 28922 mt, while the large pelagics increased to 12937 mt. Without the sardines, small pelagics contributed 16704 mt and the sardines contributed 88908 mt. The annual average small pelagic with sardines' values increased to 36,081,000 RO compared to an increase in the demersal values to 21,286,000 RO. The large pelagics decreased, on the other hand, to 9,290,000 RO.

Without the sardines, the small pelagics contributed an average of 9,671,000 RO per year compared to 26,410,000 RO by the sardines alone.

Table 5. Total sardine local price per ton per region during the three identified periods.

	Price RO per ton				Price RO per ton			
	1995-2011				2012-2020			
	Average	Max	min	slope	Average	Max	min	slope
Musandam	208	382	101	-1.9	263	487	194	-10
Al-Batinah	250	469	149	6.1	296	494	164	-46
Muscat	233	627	125	9.3	323	608	170	-53
Al-Sharqiyah	154	250	84	4	82	119	45	-3
Al-Wusta	154	335	55	5.5	142	464	45	-30
Dhofar	123	207	76	5.8	150	488	92	-25
All regions	192	268	125	1.6	132	313	60	-19
	Price per ton RO							
1995-2020	Price RO per ton							
	1995-2020							
	Average	Max	min	slope				
Musandam	228	487	101	2				
Al-Batinah	269	494	149	2				
Muscat	266	627	125	5				
Al-Sharqiyah	132	250	45	-3				
Al-Wusta	153	464	45	0				
Dhofar	133	488	76	2				
All regions	175	313	60	-3				

During the overall period 2001-2020, the small pelagic with sardines contributed 60827 mt annually to the export fish quantities versus 12623 mt and 21810 mt contribution from the large pelagics and demersals respectively. Without the sardines, the small pelagics contributed 12468 mt annually, while the sardines alone contributed 48360 mt. In terms of values the small pelagics with sardines averaged 21,871,000 RO versus 10,371,000 RO and 16,2730,000 RO from the large pelagics and the demersals, respectively. Without sardines, the small pelagics contributed an average of 7,125,000 RO per year, while the sardines contributed 14,746,000 RO per year (Table 6)

As far as the prices per ton are considered, during the recession period, 2001-2011, the prices per ton were 910 and 813 RO per exported ton for the large pelagics and demersals, respectively. The prices, however, were reported to decrease to 718 and 736 RO respectively during 2012 -2020. The overall price per exported ton for the large pelagics and the demersals were estimate to be 822 and 767 RO per

ton, respectively. The local price per ton were recorded to be cheaper than the export prices. During the period 2001-2011, the local prices per ton for the large pelagics and the demersal were 706 and 566 Ro per local ton. During the period 2012-2020 the prices per local ton increased to 1097RO and 812 RO for the large pelagics and the demersals, respectively (Table 6).

For the small pelagics with sardines included, the price decreased from 424 RO to 344 RO per exported ton and 305 to 208 RO per local ton during the period 2001-2011 and 2012-2020, respectively. While the sardines export prices decreased from 343 per exported ton during 2001-2011 to 297 RO during 2012-2020. On the other hand, the local price per ton decreased from 189 to 127 RO per ton during 2001-2011 and 2012-2019 respectively (Table 6). Total sardines export showed an increase over the years (Fig. 6). The average total sardine quantities exported during the period 2001-2020 were 48360 t per year. However, the average within 2001-2011 was 15184 t per year compared to 88908 t per year

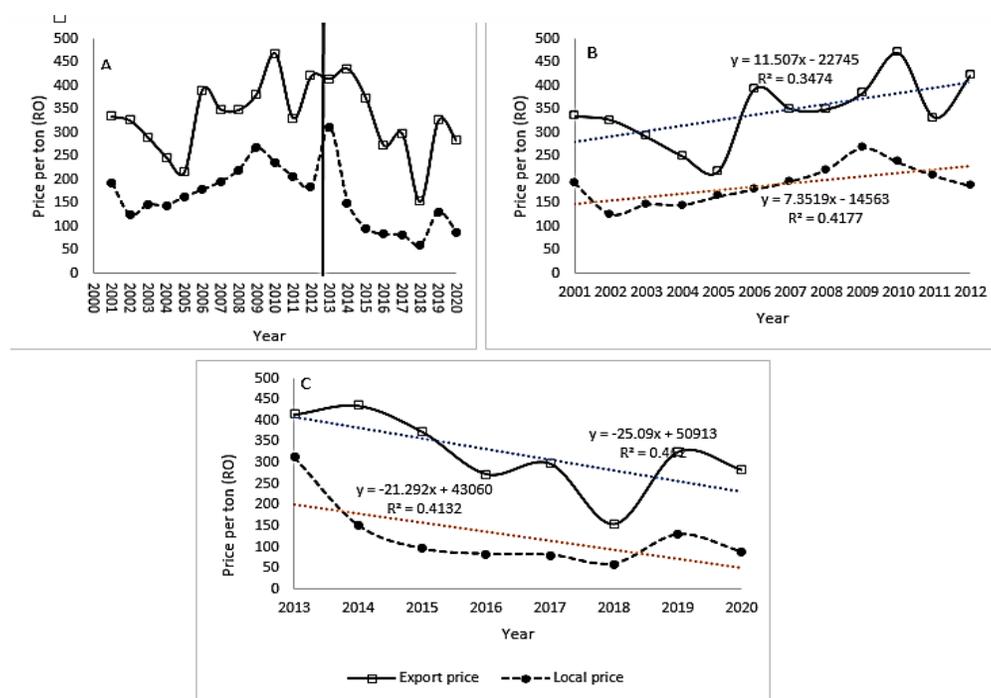


Fig.7. Local and export sardine price per ton divided into overall period 2001-2020 (A), the continues increase in the price per ton period 2001-2012 (B), and the continues decrease in the price per ton period 2013-2020 (C).

Table 6. Omani average annual fish export (quantities mt and Values *1000 RO) divided by large pelagics, small pelagics with sardines, small pelagics without sardines, Demersals, and sardines over the period 2001-2020.

	Average quantities	Average Values	RO/exported ton	RO/local ton
2001-2011				
Large Pelagics	12365	11256	910	706
Demersal	15991	13003	813	566
Small Pelagics+sardines	24185	10245	424	305
Small Pelagics-sardines	9001	5042	560	577
sardines	15184	5203	343	189
2012-2020				
Large Pelagics	12937	9290	718	1097
Demersal	28922	21286	736	812
Small Pelagics+sardines	105613	36081	342	208
Small Pelagics-sardines	16704	9671	579	591
sardines	88908	26410	297	104
2001-2020				
Large Pelagics	12623	10371	822	958
Demersal	21810	16730	767	710
Small Pelagics+sardines	60827	21871	360	231
Small Pelagics-sardines	12468	7125	571	579
sardines	48360	14746	305	127

during the period 2012-2020. The average annual total sardines exported within the last three years 2018-2020 were 131783 t. The average annual income from the total exported sardines during the

period 2001-2012 (11 years) was 5,203,000 Omani Rials. While it was estimated to be 26,410,000 RO during the 2012-2020 (9 years). Throughout the period 2001-2020 (20 years) the average annual

Table 7. Sardine export average tonnage, export average values (*1000 RO) with average price per ton (RO) per group of countries with export frequency for the last 16 years (2005-2020).

country	number of countries	Export		*1000 RO	RO
		frequency	averageTQ	averageTV	avg Tprice/t
GCC	5	14.4	83181	31001	373
Arab	7	4.4	5333	1397	262
Asia	18	4.7	16650	3591	216
Africa	15	2.5	808	159	197
Europe	8	2.0	246	99	403

sardines export income was estimated to be 14,746,000 RO. The local price and export price per ton showed two different periods, an increase in the annual prices per ton 2001-2012 (11 years) and a decrease in the local and export annual price per ton during the last 8 years (2013-2020) (Fig. 7, A, B and C). Local and export price per ton were estimated to be 189 and 343 RO/ton during the period 2001-2012, respectively. While the prices dropped during 2013-2020 to be 125 for the local price per ton and 320 RO/ton for the exported ton.

Export frequency. The results indicated that within the last 16 years the Persian Gulf Countries (GCC) has been the frequent destination for the Omani sardines (Table 7). The UAE proved to be the top sardine exporter among the GCC countries exporting an average of 14601 t per year. The GCC countries export frequency was estimated to be 14.4 years over the last 16 years. On the other hand, a total of 7 Arab countries exported sardines from Oman with an export frequency of 4.4 years over the last 16 years. Egypt, proved to be on the top of the Arab countries exporting an average of 3368 t per year. Asia countries, 18 countries in total, became more active in exporting sardines from Oman in the last 5 years.

The exporting frequency over the last 16 years was estimated at 4.7 years. Bangladesh exported the highest with an average of 17097 t annually. In Africa, exporting sardines became more popular only within the last 3 years as more countries joined the list of sardines exporting African countries Oman. As a result, the exporting frequency estimated to be a bit low, only 2.5 years over the last 16 years.

Gana exported an average of 1464 t per year, which is the highest among the African countries. Only 7 countries were reported to export the Omani sardines from Europe, Britain and France stopped exporting since 2005, while the Netherlands exported only once during the last 16 years. In 2020 only Italy and Karwata have exported the Omani sardines. The export frequency from Europe, therefore, was recorded to be only 2 years over the last 16 years (Table 7). Although Europe export frequency is very low, the export price per a ton of sardine is the highest, 403 RO/ton. On the other hand, the GCC countries came in the second place with 373 RO/t, a 30 RO more than the Arab countries price per exported ton. Finally, Africa countries pays the minimum to the exported Omani sardines, only 197 RO/t (Table 7).

Average Price per exported ton. Although the export frequency, the number of exporting countries, and the average exported annual tons are proved to be the minimum among other nations, European countries paid the highest per sardine exported ton. The European countries paid 403 RO/ton with an average annual exported quantity of 246 tons. The GCC countries paid 373 RO/exported tons with the highest average exported quantity per year. Asian countries, on the other hand, export a lot of sardines but pay only 216 RO per exported ton.

DISCUSSION

Fisheries (commercial, artisan, recreational harvest) are an ecosystem service that can play a vital role in providing employment and nutrition in the global food system (Daily et al. 1997; Holmlund & Hammer 1999). Fisheries are a source of nutrition for

many people of the world, ranging from the primary source in some developing countries and for some local communities to a supplemental, but still important, source in other places (Béné et al. 2015). Insufficient protein in many developing nations leads to human health issues (Golden et al. 2016). It shows that this important industry involves in food and health security of the people and should be considered. In the other hand, fisheries production shows fluctuation over time due to several factors. In situations of persistent over-harvesting, or fishing affecting critical habitat, or removals altering the food web and ecosystem function, a fishery becomes a stressor (Chapman 2017; Worm et al. 2009). Proper management of a fishery involves considering the biology of the species, economic aspects of the harvesting, how the species fits into the broader ecosystem, and consideration of the well-being of the human communities that rely on the catch (Marshall et al. 2018). This study reveals that Oman fisheries including sardine stocks have experienced fluctuations during the last 26 years (1995-2020), showing two periods of recession (1995-2011) and upturn (2012-2020). Sardine populations globally are known to be highly fluctuating on the seasonal and decadal scales due to environmental local and global regime shifts including deoxygenation (Lluch-Belda et al. 1989, Schwartzlose et al. 1999; Al Jufaili et al 2006; Rose et al. 2019). In Oman, during the recession period (1995-2011), small pelagic landings, mainly sardines, were low (less than 50,000 t). It might be due to heavy fishing in the previous years, environmental conditions and low number of fishermen and boats. It has been shown that, heavy fishing when coupled with negative environmental conditions could cause a serious sardine stock depletion (Peck et al. 2013; Kripa et al. 2015, Al Jufaili & Piontkovski 2020).

However, in the second period, small pelagic landings, mainly sardines, increased dramatically in Oman starting from 2012 (about 70698 t small pelagics, 43549 t sardines), reaching a peak of 530022 t small pelagics and 430243 t sardines in

2020. Interestingly, during this second period, the sardine landings were reported to be the lowest in India. The sardine landings in India have fluctuated and reached as 390,000 thousand tons in 2012 to less than 50,000 only in 2019 (Kripa et al. 2018). In 2012, the Indian oil sardine landings from southern Arabian Sea peaked to an all-time record making it the fifth largest sardine fishery in the world, and within 3 years the catches were reduced to nearly a tenth of that level (Kripa et al. 2018). The 2012 mega harvest in the southern Arabian Sea was a result of a 2-time increase in gear size and engine capacity of fishing crafts and a 3.7-time increase in fishing effort (Kripa et al. 2018). The female maturation process was strongly influenced primarily by rainfall and then by upwelling and the resulting influx of cold nutrient-rich water in the habitat from April much before the start of the monsoon in June. After 2013, the weak monsoons and the 2015 El Nino Southern Oscillation resulted in a warmer (by an average of 1.1C) period which negatively impacted the maturation process (Kripa et al. 2018). Moreover, the abundance of jellyfishes which are larval and young fish predators in the habitat, negatively affected recruitment after 2013. The mismatch in timing of phytoplankton productivity and sardine larvae in the habitat also affected the recruitment success. These environmental divergences coupled with the excessive capture (beyond maximum sustainable yields) of spawning stock and juveniles from 2010 has resulted in this biological catastrophe which has been affected the livelihood of thousands of small-scale fishers. A more responsive fisheries administration with timely restriction on fishing effort and protection of spawning stocks by way of fishery closure would have helped minimize the impacts (Kripa et al. 2018). In India, sardines are used as food for cultured fish and shrimps. In addition, the sardine is used to extract Omega by the companies in many countries (Mahrus et al. 2020). The decrease in the sardine landings in India have directly affected these two industries. The sardine fish meal and Omega extraction industries found the Omani sardines as an excellent alternative to cover

the sardine shortage in India. The total sardines exported to India increased from 56 tons in 2009 to 19798 tons in 2020 (MAF). In addition, the number of sardine meal companies in Oman increased in the last few years due to the international market demand.

The Omani sardine landings increased rapidly which caused the local and the exported price per ton decrease due to the supply and demand concept. Overall sardine prices per local kg decreased from 192 RO/t during low landing periods (1995-2011) to 132 RO/t during high landing periods (2012-2020). In Al Wusta and Sharqiyah regions the prices decreased the most due to the high sardine supply presented by the two regions. During the period 2012-2020 both regions contributed 82% of the sardines decreasing from 52% during 1995-2011. Hence, the prices decreased per ton from 154 to 84 in Sharqiyah and from 154 to 142 in Al Wusta region. These decreases reflect the decrease also in the prices per exported tons which also decreased over the years. This leads to the conclusion that increase in the sardine's landings in the past 9 years does not benefit the country economically when compared to the landing quantities. The local sardine's prices in India based on availability range between 0.32 to 0.63 RO/ton but reported to reach 1.58 RO per kg (Prakasan et al. 2015). The Omani sardines displayed in the local Indian markets are sold in higher prices than the local Indian sardines. The exported Omani sardines were reported to worth 1.05 RO per kg, while the price for the local sardines in India ranged only between 0.53-0.74 RO per kg (Prakasan et al. 2015).

The Omani small pelagics were heavily targeted in the last 10 years and sardine fish meal companies increased in number and in their capacity and technology. In 2020 the traditional fishery has contributed 94% to the total fish landings in Oman. This is done by using traditional fishing gears and motorised fiberglass boats that ranges from 5-9 m. These boats accounts for 98% of the total fishing boats used by the traditional fishermen, the rest 694 boats, are boats that ranges from 12 to 32 m which

are mostly found in South Sharqiyah governorate. The total number of licensed traditional fishermen has picked to 54969 in 2020 compared to 49715 in 2018. (MAF. 2018; 2020). Based on the presented data, sardine fishery along the Omani coast is rapidly increasing. However, so far, is not managed and there is a need for an urgent conservation and recovery plans before it is too late. In India, sardine landings were reported as high as a half million tones before it dropped to less than 55 thousand tons only in 2012, a scenario that could repeat itself in Oman.

RECOMMENDATIONS

Due to the increase catch of sardine and continues decrease in the income, sardine landings must be maintained according to the identified sardine's biomass per given region, north versus south regions. Sardines fishing effort, must be carefully controlled and defined via a licensing system. License for sardines fishing along the affiliated fishing gears must be defined per seasons and regions. Sardine landings must be controlled to only 50% of what is caught currently. To make sure of the sardine's companies' productivity, all sardines processing companies should fulfill high operating standards and the end product quality must be according to the standards of the International European markets. Sardine fishery must be closed every three years for at least one year to allow a fully recovery sardine stocks. In the scientific community, study of reproductive biology, population dynamics and food and feeding habits of sardines are highly recommended. Monitoring of the population size of jellyfishes which are larval and young fish predators of sardines should be taken under consideration.

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مقاله پژوهشی

وضعیت ده ساله صید ساردین ماهیان در عمان: سهم ساردین روغنی عمانی-هندی (*Sardinella longiceps* Valenciennes, 1847) ماهیان استخوانی عالی: شگ ماهیان)

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چکیده: شیلات یکی از بخش‌های اصلی در اقتصاد عمان می‌باشد که حدود ۵۴۹۶۸ شغل مستقیم را در سال ۲۰۲۰ ایجاد کرده است و صید ساردین ماهیان ساحلی بخش عمده‌ای از درآمد این کشور را تشکیل می‌دهد. در این مطالعه، نوسانات فراوانی ساردین ماهیان به‌ویژه گونه *Sardinella longiceps* یک ماهی دریایی کوچک استوایی، طی سال‌های ۱۹۹۵ تا ۲۰۲۰ در عمان بررسی شد. نتایج نشان می‌دهد که ذخایر ساردین ماهیان شیلات عمان طی ۲۶ سال گذشته (۱۹۹۵-۲۰۲۰) نوساناتی را نشان می‌دهد که دو دوره رکود (۲۰۱۱-۱۹۹۵) و رونق (۲۰۲۰-۲۰۱۲) را نشان می‌دهد. در دوره دوم، برداشت ذخایر پلاژیکی کوچک، عمدتاً ماهی ساردین، از سال ۲۰۱۲ (حدود ۷۰۶۹۷ تن) در عمان افزایش چشم‌گیری داشته و به مقدار اوج خود یعنی ۵۳۰۰۲۲ تن در سال ۲۰۲۰ رسیده است. که نشان می‌دهد که در طول ده سال گذشته این ذخایر به شدت مورد هدف واقع شده‌اند. با این حال، ذخایر پلاژیکی دریایی تاکنون مدیریت نشده است و نیاز به یک برنامه حفاظتی و بازایی فوری قبل از اینکه خیلی دیر شود، وجود دارد. در هند، برداشت ساردین ماهیان تا نیم میلیون تن تا قبل از کاهش به کمتر از ۵۵ هزار تن در سال ۲۰۱۲ گزارش شده است، سناریویی که ممکن است در آینده نزدیک در عمان تکرار شود. برای غلبه بر این، برآشت ذخایر ساردین باید بر اساس زیست‌توده شناسایی شده آن‌ها در هر منطقه خاص حفظ شود، تلاش صیادی باید به دقت کنترل و از طریق یک سیستم مجوزی تعریف شود، صید ساردین‌ها باید هر سه سال یکبار به مدت حداقل یک سال متوقف شود تا امکان بازایی کامل ذخایر فراهم شود. ذخایر ساردین، زیست‌شناسی تولیدمثل، پویایی جمعیت و عادات غذایی و تغذیه‌ای باید با جزئیات بیشتر مورد مطالعه قرار گیرد و اندازه جمعیت عروس دریایی که شکارچی لارو و ماهی جوان ساردین است باید بررسی شود.

کلمات کلیدی: شیلات دریایی، شگ ماهیان، نوسانات تولید ماهی، اقتصاد عمان.