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A Preliminary Investigation on the Omani Sardines and Anchovies Stock Fluctuation; Recommendations for Future Studies

Al-Jufaili Saud Musallam, Al-Azri Adnan Rashid and Al-Shuaily Sulaiman Salim
Department of Marine Sciences and Fisheries, College of Agricultural and Marine Sciences,
P.O. Box 34 Al-Khod 123, Sultanate of Oman

Abstract: This study investigates indications of inverse cyclic behavior in sardine and anchovy populations in Oman. Until now, there has been a general scarcity in the amount of research conducted on sardines and anchovies in Oman. The limited accessibility to research material made it difficult to draw strong conclusions about possible sardine-anchovy alternations. Therefore, a set of interview questions was developed and a series of interviews conducted with sardine-anchovy fishers in Oman. Based on the interviews results and review of literature on the fisheries in the region of Oman, recommendations have been developed on how to proceed with the research, management and development of the Omani sardine and anchovy fisheries. Sardines and anchovies in Oman are secondary targets to the fishers and landings are a function of market demand. The fishers provided no evidence that sardines and anchovies in Oman are inversely related. However, the fishers' experience with the sardines and anchovies is limited by the primitive fishing technology they use and their poor interest in the two fish stocks due to lower economic value.

Key words: Oman, sardines, anchovies, fluctuation, cycle behavior

INTRODUCTION

Fishing remains a vital life line for the local community in the Sultanate of Oman one of the developing countries in the Middle East that has access to a rich fishery stock in comparison with its neighbors. The Omani total coastline is estimated to be 3165 km with valuable resources like abalone, lobsters, tunas, kingfish, small pelagic fishes and many other exploited stocks that substantially contribute to the total income of the country. Most, Omani fishermen use artisanal fishing methods and only operate near shore and never exploit offshore stocks.

In the Muscat region in 1994, excessive landings of sardines (mostly by artisanal fishermen) was worth 4.2 million Omani Rials (OR) (10.8 million US dollars) which was 45% of the total fisheries revenue reported by Muscat region fisheries (Dorr III, 1991; Anonymous, 1995).

Sardine fishermen in Oman use mostly traditional beach and purse seines, which require little effort but are rarely deployed far from the beach. Sardines are dried in the sun and used as fertilizer, as food for cattle and humans, or as bait. Anchovies are utilized similarly as sardines and are caught mostly by the same fishermen, with the same gear. So far, Oman has had large catches of sardines but not of anchovies. No studies have been conducted yet to estimate the biomass of this fish stock and no one has carefully studied the landings of this fishery.

A literature review showed that sardine and anchovy stocks from California, Japan, Peru and from South Africa fluctuate in an inverse manner. The available evidence suggests that long-term environmental changes trigger the sardines and anchovies stocks to alternate in abundance. As the sardines or anchovies expand they cover a much wider geographic range along the coastal region. This expansion is a function of having optimal environmental conditions along the coast. Sardines (or anchovies) persist in high abundance for as long as the optimal conditions exist (typically for a period of 30 to 50 years,) before abundance collapses and the range shrinks. When the sardine (or anchovy) population shrinks, the fish retreat to refuge areas that allows the population to exist and reproduce even though the other fish population has become dominant. When the environment changes to favor the sardines, the anchovies retreat to their own refuge areas while the sardines expand.

Given the dramatic changes that occur in the major sardine-anchovy systems, an essential step to better understand the Omani sardines and anchovies is to define whether they behave in a similar inverse cyclical manner

Corresponding Author: Al-Jufaili Saud Musallam, Department of Marine Sciences and Fisheries, College of Agricultural and Marine Sciences, P.O. Box 34 Al-Khod 123, Sultanate of Oman

or not. The objective of this research; therefore; is to investigate whether the sardines and anchovies in Oman are inversely related or not. Based on the results we develop recommendations on how to proceed with research, management and development of fisheries for sardines and anchovies in Oman.

MATERIALS AND METHODS

We were unable to locate any published references on the history of the fishery for sardines and anchovies in Oman. In order to fill this gap, we interviewed a number of sardine and anchovy fishers. We selected the questions for the interviews so the answers would make it easy to infer whether the Omani sardines and anchovies fluctuate inversely as in the other sardine-anchovy systems.

The interviews were conducted during June 2001 using a set of 17 questions (Appendix 1). Since most of the fishers interviewed were illiterate, the interviews were conducted face to face and verbally, rather than distributing questionnaires. Also, the oral interview format allowed us to ensure that the fishers understood the questions and that their answers were relevant to the question asked. The questions were designed for sardine and anchovy fishers that had extensive experience fishing for the two types of fish. Hence, it was made sure that the fishers interviewed were old enough to have a long historical perspective. The fishermen interviewed were from 60 to 70 years old and had at least 30 years experience in the sardine and anchovy fisheries.

The responses to question 1 indicate how long the fishermen have been in the sardine and anchovy fishery. The fishermen that had over thirty years of experience were asked the remaining interview questions. These fishermen are most likely to be able to describe any major historical changes in the abundance of sardines and anchovies.

Sardines and anchovies in the other cases studied are distinguished by their temperature tolerance, with the sardines usually preferring warm waters and the anchovies preferring cold waters. The purpose of question 2 (Appendix 1) was to find out whether the sardines and anchovies in Oman have such temperature preferences. Question 3 was included to confirm the response to question 2. If the sardines and anchovies are rarely caught together, it could be because they have different temperature preferences. Regional differences in the responses to these questions are of particular interest.

The type of gear used for sardines and anchovies and the distance offshore the fishermen operate (questions 4 and 5) probably limit the fishermen's knowledge. Catch preference may be an important issue with regard to fluctuations in the landings. The price and the use of the catch (questions 6 and 7) might orient the fishers to the more expensive fish, in which case landings fluctuations are a function of market price rather than changes in fish abundance or distribution.

Questions 8 and 9 address the phenomena of sardine and anchovy expansions and contractions, which occur in other sardine-anchovy systems (Souter and Issacs, 1969; Baugartner *et al*., 1992; Schwartzlose *et al*., 1999). The intent of the questions is to determine whether sardines or anchovies in Oman have experienced long-term or short-term disappearances and whether there are refuge areas.

Questions 10 to 13 are intended to establish the relative dominance of sardines versus anchovies and geographic details of the expansion process. In addition the questions deal with the fishermen's willingness and ability to increase their fishing activities when the sardines or anchovies increase.

Questions 14-16 deal with the importance of sardines and anchovies to the Omani fishermen compared to other fisheries. If fishers prefer other fish stocks and rank sardines and anchovies as being unimportant, then catch trends in Oman for sardine and anchovies provide a biased representation of sardine and anchovy abundance.

Finally, question 17 is a general question that explores the fishers' observations of changes in ocean conditions and whether they can relate this change in the ocean condition with changes in the sardine and anchovy availability.

A total of 30 fishermen were interviewed along the Omani coast (Table 1). The interviews covered five out six Omani regions. Musandam region was not included in the survey. A few fishers interviewed were slightly younger (from Al-Wusta), but still had extensive experience.

In most of the areas, it was difficult to interview one fisher alone. The majority of the interviews were with more than two fishers who spoke for all of the sardine and anchovy fishers in that area. Fishing operations for sardines or anchovies involve an average of 12 fishers; so the one particular fisher that I interviewed in fact spoke for the entire crew of 12. Therefore the 30 fishers that I interviewed represent roughly 360 sardine and anchovy fishers.

While interviewing the fishers, we never interrupted them and we did not follow a fixed interview protocol and sequence of questions. Rather, we allowed the fishers to describe their work and the fisheries within the general framework of the questions in Appendix 1. Even with this less structured approach, most of the answers were consistent.

Table 1: Geographic distribution of the number of fishers interviewed along the Omani coast. The regions (bold) and villages visited (normal font) are listed from North to South

Region	No. of fishers
Al-Batina	
Shinas	2
Majis	4
Saham	2
Alkhabora	3
Muscat	
Alseeb	6
Alazaiba	2
Berka	3
Al-Sharqiya	
Sur	1
Alashkhara	3
Al-Wusta	
Masira Island	2
Dhofar	
Mirbat	1
Taqa	1
Total	30

RESULTS

Sardines and anchovies are distributed all along the Omani coast. The number of full timer sardine and anchovy fishermen in Oman is small; almost 98% of them were interviewed in this study. These fishers share almost the same experience with the sardines and anchovies. As a result; the answers from these fishers were all; unanimously; in agreement. The interview results indicated a 100% agreement among fishers interviewed that there is no evidence for a long period fluctuation in the sardines and anchovies abundance in Oman. The results from different regions in Oman were all linear and normal. The summary of the sardines and anchovies stock and fishery behavior based on the interviews and per region is summarized as follows.

The abundance of the two fishes and their seasonal availability vary. The fishers interviewed agreed that the sardine season is during the cooler season of September to April, with peak abundance during December and January. The fishers added that sardines might disappear from their gears for a short period of time (up to two months), but generally they are always available somewhere along the Omani coast. Anchovies, on the other hand, do not have a particular season but could appear in Omani coastal waters at any time of the year. After appearing in coastal waters, the anchovies disappear after one to two months and hardly overlap with the sardines. The fishers agreed that sardines and anchovies are not found together and agreed that anchovies mostly tend to appear during the summer months (May-September). However, the fishers again repeated that this is not always true.

When sardines and anchovies overlap in abundance, which rarely happens, the fishers in Oman target them separately. Fishers in all regions use the same types of gear for sardines and anchovies: beach seine, purse seine and, occasionally, cast nets.

Larger mesh sizes are used for sardines and smaller and thinner mesh for anchovies. Because the fisheries occur next to the beach, the fishers can shift the gears easily to catch one species over the other, according to the market demand, especially the fishers in the Muscat region. Fishers can shift to using purse seines when the schools are big or the demand is high. In all regions, the unused gear is put aside on the beach and covered with a heavy blanket until the next season. Beach seines and purse seines are modified gillnets that require up to 12 people to set and haul. The fishers can catch from 30-40 tons a day when the sardines are plentiful. Beach seines, in general, are the most common type of gear used for sardines or anchovies. The geographic scope of the fishing operations are limited, however, by the traditional gear types used by the fishers, which can only operate near shore to depths of 3 to 5 m. Fishing also is limited by political/social boundaries with the adjacent fishing villages.

The landings of both sardines and anchovies are used as food for humans (either dried or fresh), as fertilizer (dried) and as food for cattle (dried). Even though dried sardines and anchovies fetch a higher price, most fishers only sell fresh fish because the dried fish require attention and space to prepare. Also, conflicts can arise with neighbors because of the odor resulting from the drying process.

People in the different regions prefer different fish, which is reflected in the sardine versus anchovy prices. In the Dhofar region, including Masira Island and Wusta, people always prefer sardines, which are more expensive than anchovies. In contrast, most of the people in the northern part of Al-Batina coast, Shinas and Majis like to eat anchovies, which drive up the price for anchovies in this region and explains their greater abundance in the market. Dried anchovies are brought from all over Oman to the Al-Batina market, making them plentiful there. Fishers in the Muscat area are close to the Al-Batina, yet target sardines because they are plentiful. However, the Muscat fishers do not mind fishing for anchovies when they are available due to the favorable price for anchovies in the nearby Al-Batina market. Fishers from the Muscat area also have other advantages over fishers in other regions. There are more fishing companies willing to buy sardines or anchovies at any time.

In the Al-Batina region anchovies are greatly preferred over sardines and are treated more as a delicacy than in any other region. Anchovies in this region can therefore cost twice as much as sardines. In Dhofar sardines are preferred and they exist in higher abundance. In Al-Wusta the people prefer sardines over the anchovies but fishers also monitor the Omani market demand. Hence, fishers in Al-Wusta target either sardines or anchovies according to market demand.

In the Muscat region, targeting sardines and/or anchovies depends on the fishers. There are two types of fishers in Muscat-the year-round and the part time. The year-round sardine and anchovy fishers target sardines and anchovies regardless of the market demand. The other fishers enter the fishery on a temporary basis when there is strong market demand. The year-round fishers supply the local markets and sell their surplus catches to certain fishing companies that give away these sardines and anchovies to other fishers that use the fish as bait for more valuable fishes. These other fishers, in turn, are obligated to sell their catch to the companies. The part-time sardine-anchovy fishers enter the fishery when the high demand includes nearby country markets.

Anchovies sometimes appear for short periods in very large volumes and when they do, the fishers make a good living. When there are high volumes of anchovies, numerous additional fishers enter the fishery. The fishers use the same gear to catch anchovies whenever the anchovies appear so they have no expense for new gear. The fishing is very intense on the anchovies but lasts a very short period of time.

Sardines and anchovies are sold by the truckload, with each truck holding up to one ton. The price per truckload differs from one region to another and varies according to the distance to the market place. The main markets for sardines and anchovies are located in Muscat, Al-Batina and in Dubai in the United Arab Emirates. Most of the sardines landed in Oman are sold in the Dubai market. Anchovies, however, are often sold in local markets because the demand is very high.

Because the Dhofar region is very far from all these major markets, all of region's sardine and anchovy landings are sold locally to local farmers and cattle owners when the catch is small. When the catch is larger, the fishers sell their catch to middlemen who transport the fish in refrigerated trucks to markets in Al-Batina or Dubai where the prices are higher. The farmers in Dhofar create enough demand to generate a year-round fishery for sardines and anchovies. The price in the Dhofar region ranges from 25-30 Omani Rials per truckload (1 Omani Rial is equivalent to 2.58 US dollars). In the Al-Batina region the price ranges from 50-200 O.R. per truckload.

The fishers have two ways to sell their catch to middlemen: sell directly for cash, or allow the middlemen to sell the catch in the market on commission, splitting the proceeds after deducting for the middleman's fixed costs. Some middlemen ensure their access to fish by providing the fishers with fuel and bait.

In the Dhofar and Wusta regions, the price and fish abundance must be very high for new fishers to enter the sardine or the anchovy fishery because of the greater distance between these regions and the major markets. The Al-Wusta fishers do not enter the fishery until the price goes up to 80 O.R. per truckload, at which point they transport their catch either dried or refrigerated to Muscat and Al-Batina, or to Dubai if the prices are higher.

Al-Sharqiya was the only region where there was no fishery targeting sardines or anchovies, regardless of the market demand. The fishers at Al-Sharqiya believe that sardines and anchovies are food for the larger pelagic fish species that the Al-Sharqiya region is famous for. In this area, the fishers from the ports of Sur and Alashkhara focus on tuna . The fishers believe that small pelagic fish are the primary food for the tunas and other valuable large pelagic fishes and so they rarely target sardines. The fishers in some villages in the Sharqiya region have mutual agreements to not fish for sardines in order to maintain the tuna in their waters. Target fishing for sardines is allowed only if the catch is to be used as bait for tuna or other fish. The fishers also report to the local authorities any fishers that target the sardines for any other use.

All the fishers in all the regions agreed that it is not the abundance of sardines or anchovies that is the major control over whether or not they enter the fishery; it is the market demand for the fish. When the demand for sardines increases, the fishers do not buy more gear or expand their operations. They continue fishing each day until the demand is satisfied. They believe that what they can catch in a day is enough. If the fishers need to add employees, they do so with family members and not outsiders. These part-time helpers receive wages for the short periods of employment and are laid off when their help is no longer needed. This flexibility in the fishing workforce does not negatively affect the workers or their communities. When the extra market demand for fish relaxes, the extra fishers are laid off and most fishers quit the fishery. The fishing gear is covered and stored on the beach until the next increase in market demand. The fishers also stop fishing for sardines or anchovies when there are market demands for other more valuable fish.

In the Al-Wusta and Dhofar regions, the fishers stop fishing for sardines and anchovies from June to August, when sea conditions are too rough for fishers to operate

their traditional gears (Kindle and Arnone, 2001). They resume fishing for sardines when sea conditions become favorable again. But not all the fishers follow this pattern. In some places, fishers can still fish for sardines even during the monsoon. In areas such as Mirbat in the Dhofar region, the sea is generally calm and fishers can safely operate in all seasons. None of the fishers in the Muscat and Batina regions stop fishing due to bad oceanic conditions, but they do stop fishing when there are poor market conditions or the fish are unavailable.

Around Masirah Island in the Al-Wusta region, the fishers indicated that anchovies could always be found in deeper waters or in specific geographic locations but they are not targeted. Other fishers from Muscat pointed out that anchovies are always present in coastal waters in areas such as Khabora, Shinas and Majis along the Batina coast. When the fishers from these areas were interviewed, they all answered the questions no differently than the others from Muscat. The fishers find anchovies only for a short time but have sardines almost all of the time.

The fishers generally believed that sardines were present in Omani coastal waters all year and in greater abundance than anchovies. However, the fishers from Al-Wusta said that anchovies were more abundant in the 1970s and the fishers from Al-Batina said that anchovies were more abundant in the 1950s. During those periods the sardines did not have a defined season. The fishers did not remember how long the anchovies remained plentiful before they disappeared. The fishers from Muscat and Dhofar also indicated that anchovies had been abundant in the past but they did not know when. The fishers from Al-Sharqiya never targeted sardines or anchovies and therefore were not familiar with their patterns of historical abundance.

The fishers interviewed did not indicate any notable relationship between changes in sea conditions and changes in the sardine and anchovy populations. However, they did say that when anchovies were available more fish in general were available, including tunas and kingfishers. The fishers from Al-Batina and Muscat said that even agriculture was much better during those periods.

DISCUSSION

There was no evidence from the fishers that the abundance of sardines and anchovies in Oman is inversely related. This contradicts with the California, Peruvian and Japanese sardines and anchovies cases discussed in Al-Jufaili's Ph.D. The results; however; are in agreement with the studies of sardines and anchovies in the Indian Ocean which do not show any inverse relation, although these studies indicate short-scale fluctuations in sardine biomass (Fig. 1) data obtained from (FAO, 2000). The reason given was that poor year classes resulted when summer monsoon conditions had an adverse effect on sardine spawning (Gopinathan, 1974; Raja, 1973). Temperature and salinity fluctuations were associated with rapid declines in the Indian oil sardine population, particularly in the juvenile portion. Low sea surface temperatures prevent the juvenile sardines from entering the fishing grounds (Bensam, 1970). Increased phosphate concentrations in the water during the monsoon were also found to be associated with decreases in the sardine biomass (Subrahanyan, 1959; Annigeri, 1969). Based on the literature review, there is no evidence that sardines and anchovies in the Indian Ocean undergo 30 to 40 year alternations as it occur in Peru, Japan and California.

There are a number of cyclical environmental changes that induce variability in the abundance of sardines and anchovies around the world. These environmental changes involve changes in the sea surface temperature

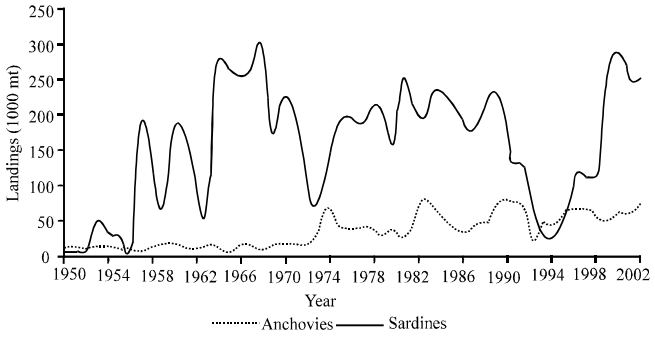

Fig. 1: Western India total sardines and anchovies landings. Data obtained from FISHSTAT Plus: Universal software for fishery statistical time series. Version 2.3 2000

and corresponding atmospheric changes due to the shifting air-sea relation. Sardines and anchovies fluctuate in abundance as the environment shifts from one regime (cold) to another (warm). Yasuda *et al.* (1999) Show similarities between the abundance of the Japanese sardine and the regime shift indexed by North Pacific Index (NPI). Scientists were able to identify a similar relation in the Indian Ocean between the ocean and sea surface temperatures which causes interannual climate variability. The Indian Ocean air-sea interaction, called the dipole mode (Saji *et al.*, 1999) is believed to be independent from the ENSO.

The dipole mode events are characterized by cooler sea surface temperatures off Sumatra in the southeast tropical Indian Ocean when the western tropical Indian Ocean is warmer than usual. It is also characterized by strong easterly winds along the equator in the tropical eastern Indian Ocean. To quantify the dipole mode, researchers defined an index called the dipole mode index. During a positive dipole event, there are warm Sea Surface Temperatures (SST) in the regions around Oman; there are cold sea surface temperatures during a negative dipole event. This dipole phenomenon occurs about every four to five years in the Indian Ocean (Saji *et al.*, 1999). The dipole mode, however, does not correlate with the landings of sardines or anchovies in the Indian Ocean and it is not known how -it affects their abundance.

When compared with the sardine and anchovy species of California, Peru, Japan and South Africa (Al-Jufaili, 2002); Oman has many more species of each, six sardine species and six anchovy species. In the other sardine-anchovy systems there is generally only one species of sardine and one anchovy. The variety of sardine and anchovy species in Oman could indicate greater diversity of environmental habitats when compared to the other sardine-anchovy systems. This diversity allows or perhaps encourages speciation.

The sardine and anchovy species found in Oman are also found in the countries that border the Indian Ocean. The seasonal shift in winds due to changes in the Indian Ocean atmospheric pressure in summer versus winter causes reversals of the current along the coast of East Africa that extends to Oman and Iran (Sheppard, 2000). The existence of several species of sardines and anchovies along the Omani coast could be due to the migration of fish to the north during the southwest monsoon and southward during the southeast monsoon.

The geography of the area around Oman is also diverse. The oceanic bodies include the Arabian Gulf (Persian Gulf), the Red Sea and the Gulf of Oman. This diversity of environments could be the reason for the existence of so many species. Some of the sardine and anchovy species in the region have been recorded in the Red Sea but not in Oman; others have been reported in northern Oman but not in the south. In California, Peru, Japan and South Africa the geographic diversity is much more limited than around Oman.

It is easier for the inverse cyclic behavior to occur in a system composed of two species, one sardine and one anchovy, than in a system with six species of sardines and six of anchovies. A system with so many species of sardines and anchovies indicates a diverse system supporting speciation. A system with only one species of each suggests that a homogenous system does not support speciation. Therefore shifts in the environment in a homogenous system are likely to either support the one species or the other. In a diversified system, it is difficult to conceive how an environmental change could support the complete set of, say, the anchovy species and depress the set of sardine species, while simultaneously providing sufficient diversity to maintain all the individual species within each set.

Some of the fishers in Oman indicated that when anchovies used to be plentiful, agricultural production was much better and fish were more abundant near the shore. One possible reason for the decline in agriculture could be the construction of dams that occurred in Oman during the 1980s. The dams might prevent underground fresh water from reaching the coastal agricultural areas in Muscat and south Al-Batina resulting in the groundwater becoming more saline. However, we can not see any relevant relation to anchovy or sardine abundance All the fishers complained about declines in overall fish landings. In the 1970s and 1950s, the overall fish landings were much larger than now. The fishers related these years with the high abundance of anchovies as well. The fishers all agreed that the bigger vessels that now fish in the offshore waters are the reason behind the decreased availability of fish inshore. The offshore fishing fleet did not operate in Omani waters until the 1980s.

Regarding possible refuge areas for anchovies, some fishers indicated that anchovies are always abundant in Al-Batina coast, but the fishers from Al-Batina denied that anchovies are always present in their waters. The fishers from Al-Batina suggested that the demand for anchovies in Al-Batina is always high and that fishers from all over Oman bring their anchovy catch to the Al-Batina market. Although anchovies might always be available in the market, they are not always in the waters around Al-Batina.

The sardine and anchovy cyclic behavior in Oman is not evident as far as the results of this study are concerned. The fishers' knowledge of expansions and contractions of sardines and anchovies, however, is

limited by their small-scale fishing technology and the relatively low importance of these two fish stocks to the Omani fishers. We found that the current results need to be confirmed due to the following reasons. First; the total number of full timer sardine and anchovy fishers in Oman is very small; the rest of the fishers enter into the fishery whenever there is a high demand for these two fisheries. Therefore; the experience of what is really happening between the sardines and anchovies is very limited. Second; the sardine and anchovy landings are not representative and can not be used to conclude any fluctuation patterns between the two fishes due to the small number of fishers involved into the fishery and due to the traditional fishing gears used. Third, the sardine and anchovy fishing activities are limited to up 5 m deep waters. This does not tell whether the sardines and anchovies can be found in deeper waters or not. Due to these reasons, the current results are limited only to coastal sardine and anchovy fisheries. The results of this research could be better had the fishers explored more fishing grounds. Hence, the current study should be considered only as a preliminary investigation into the fluctuation phenomena between the sardines and anchovies. The following sections include recommendations on how to proceed with the Omani sardine and anchovy fisheries.

FUTURE OF THE OMANI SARDINE AND ANCHOVY FISHERY

Based on the interviews with sardine and anchovy fishers in Oman, the lessons learned from other sardine-anchovy systems, the points given below should be addressed for managing and developing the sardine and anchovy fisheries in Oman. Although dramatic alternations in sardine and anchovy abundance are not an important feature in Oman, there are other crucial issues that should be considered.

Research issues: The diversity and stock composition of Omani sardines and anchovies should be closely studied. It is important to identify the less abundant species because in a mixed-stock fishery it is possible to drive the less productive stocks to extinction even when overall rates of exploitation are moderate. The sardine and anchovy fishers in Oman use the same gear to fish all the sardine and anchovy species. If the weaker species intermix on the fishing grounds with the productive ones, the lack of differentiation by the fishing operations could unknowingly harm the less abundant species. Therefore, research is needed to monitor the species composition of the sardine and anchovy catches in Omani waters.

Knowledge of where and when the sardines and anchovies live, spawn and feed is important for determining whether Oman needs to collaborate with neighboring countries to study and manage the fish stocks. Defining concentration areas or spawning areas along the Omani coast is the current priority because there is a danger that fishers might unknowingly discover and target these zones when market conditions are favorable. These zones should be identified by egg and larva surveys and the characteristics of the fish populations in them carefully studied. Closing these zones to sardine and anchovy fishing and restricting the by-catch of sardines or anchovies through gear changes may be necessary. Special attention should be given to the anchovy populations because they exist in lower abundance than the sardines. Increases in market prices could encourage the fishers to overexploit anchovies if fishing is not controlled. Sardines and anchovies are short-lived species and high levels of exploitation could result in recruitment failure and a succession of poor year classes. So far, fluctuations in sardine and anchovy landings in Oman have been due mainly to changes in market conditions.

Studies of the relationships between sardines and anchovies and conditions in their spawning areas are very important for understanding the preferred environments. The dynamics of the local ocean environment in Oman needs to be more closely studied to establish the oceanographic processes that generate the conditions preferred by sardines and anchovies. Correlation studies should be conducted among the local ocean environment and atmospheric change and the response of the sardines and anchovies to such changes. For example, upwelling indices, sea surface temperatures, salinity and the type and amount of food available should be correlated with the sardine and anchovy spawning activity. These variables proved to be important in the sardines and anchovies life cycles in the cases studied. Therefore measurements of these variables should be taken on a regular basis. Long term environmental data are important for understanding fluctuations in the sardine and anchovy catches. Ocean currents and the monsoon cycle in Oman and their combined effect on the sardine and anchovy populations are poorly understood at present and should be also studied.

Management issues: The sardine and anchovy fisheries are a secondary source of income for most fishers in Oman. Consequently, a simple form of management should control the fishery, although greater complexity may be required if the fisheries develop. The fishers involved in these two particular fisheries and the gears

they use should be licensed, with the government limiting the number of licenses according to their assessment of the stocks via monitoring of the landings. Because the fishery is market driven, closed seasons or areas could be established as needed to protect the spawners or the less abundant species.

To avoid the involvement of too many fishers when the market price increases, the number of fishers has to be controlled. Fishers who are licensed to harvest sardines and/or anchovies could transfer or sell their license to other fishers. Since no harvest quota is involved, only licenses are going to be transferred and the transaction might involve new fishers. License transfers or sales should be officially registered to keep track of the license holders

The middlemen in Oman manipulate the fisheries because they monitor the market prices. The number of these middlemen should be controlled. As more middlemen become involved, there could be more pressure to catch sardines and anchovies during periods of high demand. The middlemen who transport sardines and anchovies within Oman or to neighboring countries should be licensed as well. Border taxes can be established on the middlemen as needed.

RECOMMENDATIONS

The following recommendations are in priority order.

Recommendation 1: Study and describe the Omani sardines and anchovies, their environment and their interactions with other species: The most immediate task is to determine the magnitude of the sardines and anchovy stocks in Oman. Sardine and anchovy population size can be assessed acoustically as is done with the stocks in South Africa. Acoustic techniques involve the use of an echo-sounder or sonar to estimate the dimensions and packing densities of schools of fish. Pulses of acoustic energy released from an echo-sounder strike the fish school and bounce back to be detected by a transducer. Fish then may be counted and their size estimated by the density and amplitude of the echo signals. Mark-recapture methods also can be used to estimate and assess stock size. A known number of marked fish is released into a fish stock. The proportion of recaptured marked fish in subsequent catches is used to estimate the stock size (King, 1995). These methods of stock size estimation can be repeated as needed.

Sardine and anchovy spawning grounds can be identified through egg surveys and gonad studies Thereafter, different environmental measurements should be taken in the identified spawning areas, including sea surface temperature and upwelling indices. The environmental data should then be correlated to the sardines and anchovies spawning activities. Having better knowledge of these spawning areas will allow the fishery managers to protect the areas and close them whenever it is necessary. More studies on the food habits of pelagic fish species should be conducted so that there is better understanding of the linkages between prey species such as sardines and anchovies and the valuable predator species such as tunas and kingfish. In the past, the Omani government has supported development of fisheries that target large pelagic fishes. It may be very important to preserve the small pelagic fish species as a food resource for these larger, more valuable fish.

Sampling programs for collecting long term environmental data should be established in Oman and the data evaluated in relation to changes in the sardines and anchovies stocks. Measurements of sea surface temperature, air temperature, wind direction and speed, salinity and phytoplankton and zooplankton concentrations should be regularly collected from different stations along the Omani coast.

Recommendation 2: Establish a sardine and anchovy management plan and fishers license system and monitor effort and landings: Stock assessment and monitoring techniques for sardines and anchovies should be designed to minimize the risk of underestimating the amount of fish harvested and landed. To assist the monitoring process, the government should license the number of fishers and the types of gear. Better reporting mechanisms for catch and landings need to be designed and implemented. Additionally, to improve the tracking of landings, the middlemen should be licensed to transport sardines and anchovies across the border.

Recommendation 3: Develop the sardine and anchovy fisheries cautiously: In general, the landings of sardines and anchovies are highly variable. This variability can be of serious consequence for fishers that become overly dependent on these fish species. Full development of the Omani fisheries for sardines and anchovies will make both fishers and industry subject to fluctuations in abundance. Fluctuating fish stocks will result in variable market prices, which, in turn, influence the fishers' earnings.

Development of a modern fishery for sardines and anchovies would require education of the fishers and financing of new equipment. The fishers would have to replace their boats with larger ones that can travel further offshore and deploy larger fishing nets to catch more sardine and anchovies. This will be difficult because the fishers at present cannot afford to buy new boats.

The Omani fishers do not complain about fluctuations in the abundance of sardines and anchovies because they do not depend completely on them. In fact, fishers mostly catch sardines and anchovy stocks when prices are favorable. Establishing steady markets for sardines and anchovies is likely to be the factor limiting development of these fisheries.

The critical question that the Omani fisheries sector and stakeholders must answer is whether sardines and anchovies in Oman are worth all this attention. In the author's view, the answer is yes, but not necessarily for direct economic reasons but rather to preserve the sardines and anchovies as feed for other valuable fish species.

Appendix 1

The questions used in interviews with the fishers in Oman

- How old were the fishermen and how long had they been in the sardine/anchovy fishery?
- What are the sardine/anchovy seasons? Are the seasons related to cold versus hot months or to the monsoon?
- Are sardines/anchovy caught together in the same gear?
- What type of gear is used for the sardines and anchovy and which gear types are preferred and why?
- How far along the shore and offshore does the fishery occur for sardine/anchovy?
- How are the sardine and anchovy used and how much are they worth?
- Which of the two types of fish do the fishermen prefer to fish for and why?
- Have there been periods when sardines/anchovy disappeared for a long time? If so, for how long did they disappear before returning? Do the two types of fish disappear at the same time or do they alternate?
- When sardine/anchovy disappear do they disappear completely or can they still be found in some places? Where?
- Sometimes a number of fishermen share the same gear. What do they do when the sardines increase or decrease? Do they buy more gear and fish separately?
- When sardine/anchovy populations increase/decrease, do the fishermen increase their fishing frequency? Do they hire new employees to increase their fishing activities? What do the fishermen do with the extra gear and employees (if any)?
- When sardine/anchovy return after a long disappearance, which of them come back in higher numbers?
- When sardine/anchovy expand do they expand along the shore or offshore?
- Are there periods when the fishermen stop fishing sardine/anchovy even though they are available? Why do they stop fishing? For how long?
- Do the fishermen catch for other types of fish besides sardines/anchovies?
- When fish other than sardines/anchovies are available do the fishermen continue their sardines/anchovy fishing or do they decrease their activities so they can catch other fish as well?
- Have the fishermen noticed any changes in the oceanographic conditions (water temperatures, currents, or appearance of rare species) that they think might be related with changes in sardine and anchovy abundance?

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