OMAN FISHERIES DEVELOPMENT AND MANAGEMENT PROJECT

FISHERY MANAGEMENT PLAN

FOR THE

TRADITIONAL KINGFISH FISHERY

IN THE

SULTANATE OF OMAN

Amendment 1

RECOMMENDED MEASURES TO MANAGE KINGFISH

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RECOMMENDED MEASURES TO MANAGE KINGFISH

I. INTRODUCTION

This document amends the *Fishery Management Plan for the Traditional Kingfish Fishery in the Sultanate of Oman* (Hooker and Parsons, 1995) (Kingfish FMP) to include sections on the measures recommended to attain the management objectives, the rationale for choosing the proposed management measures from among the alternatives considered, and a discussion of the net benefits to be obtained from implementing the measures. In addition, the amendment addresses enforcement considerations, information needs, likely future management needed, and additional supporting information. This amendment expands upon the management alternative selected by the Kingfish Task Force, and is the next step in the logical progression of the kingfish management process.

A. Goal To optimize the social and economic benefits of the kingfish fishery.

B. Problem

Overfishing on adult and juvenile fish has caused large declines in catch since 1988.

Fishing effort greatly exceeds the level necessary to harvest the stock at the maximum sustained level.

II. RECOMMENDED MANAGEMENT MEASURES

Restrict mesh size to a minimum of 14.6 cm (stretch mesh) and prohibit possession of kingfish less than 74 cm forklength. This will reduce fishing pressure on young kingfish, allowing more to reach sexual maturity and to reproduce.

Limit fishing effort per vessel by limiting the length of individual and combined headlines of gill nets for each vessel in the kingfish fishery. Individual nets will be limited to a maximum headline length of 112 m. Vessels over 10 meters will be allowed to fish nets with combined headline lengths up to 990 m. Vessels under 10 meters will be allowed to fish nets with combined headline lengths up to 560 m.

Apply management measures everywhere within the Exclusive Economic Zone of the Sultanate of Oman and during all seasons.

III. RATIONALE FOR SELECTING THIS MANAGEMENT MEASURE

The selected management measure promises to provide the largest increase in catch of those measures considered. The other options considered in the management plan for limiting effort on young kingfish by restricting mesh size, were not expected to produce as large an increase in catch. The restrictions on total amount of net fished per boat were added to limit fishing effort per boat to current levels.

Those options proposing to limit licenses were not projected to affect stock size and subsequent catches in the near term, because the number of licenses proposed would not have reduced effective effort from present levels. License limitations were considered as a longer term method for controlling effort in conjunction with protecting small fish through size limits on fish and mesh size regulations and, eventually, for serving as a basis for allocating shares of an overall catch quota. Given the presently unregulated state of the traditional fisheries in Oman, restricting access to the kingfish fishery by limiting licenses was not considered socially acceptable or politically feasible.

IV. CONSEQUENCE OF NO ACTION

If no management measures are implemented, annual catch is projected to remain equal to that reported for the 1993/94 season at about 3,800 mt; ex-vessel price is projected to remain at RO 0.950 per kg; and participation in the fishery is projected to remain at about 450 active vessels targeting kingfish.

All of this assumes that economic and environmental conditions remain the same as assumed in the Kingfish FMP, and that fishermen and the kingfish stock will continue to respond in the same manner. The average projected yield of 3,800 mt is assumed to be a long-term sustainable yield, given the present level of effort on the stock and average environmental conditions, and is significantly below the potential long-term sustainable yield of about 10,000 mt/year as discussed in the Kingfish FMP.

Scenarios for several likely changes in economic and environmental conditions can be described. (1) If exvessel price increases, in response to population increases in Oman and the UAE, then fishing effort is likely to increase, resulting in an initial increase in catch but eventually driving down stock size and resulting in decreased average annual catches. (2) If environmental conditions result in recruitment failure in a given year, then catches will decline. At extremely low levels, the stock may not be able to recover. (3) However, it is possible that environmental conditions could result in an unusually high recruitment in a given year, which could result in increased catches in the following few years with an eventual decline to the assumed equilibrium catch of 3,800 mt/yr. For example, the 1995 kingfish landings in Oman are estimated to be about 6,100 mt. There is no information that effort has

changed significantly (see Table 1), indicating that the increase in catch is due to a good recruitment event.

Combinations of changes in economic and environmental conditions can lead to a variety of results that may differ from the projected average. Most changes in economic conditions are likely to lead to increases in fishing effort. Random fluctuations in environmental conditions will lead to unpredictable changes in recruitment and subsequent catches. In general, increasing effort levels will reduce the effect of good recruitment events on catches through growth overfishing, while exacerbating the effects of poor recruitment events through growth and recruitment overfishing.

Table 1. Number of launches and fiberglass boats by region and estimated number of fishermen by region, 1993 and 1994; and kingfish landings by region 1993, 1994 and 1995, Sultanate of Oman.

Region/Item	Launch[1]		Fiberglass[1]		Total Boats[1]		Estimated Number of Fishermen[2]		Landings (mt)		
	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994	1995
Musandam	88	76	1,026	528	1,114	604	2,492	1,575	353	239	231
Batinah	15	0	2,905	2,488	2,920	2,488	5,885	5,544	753	1,022	3,075
Muscat	6	3	1,335	1,367	1,341	1,370	2,700	3,062	336	711	760
Sharqiyah	219	236	1,463	1,264	1,682	1,500	4,021	4,053	1,145	1,449	1,923
Al Wusta	29	25	1,159	761	1,188	786	2,463	1,827	466	370	84
Dhofar	14	6	1,268	1,331	1,282	1,337	2,606	2,997	89	55	57
Total	371	346	9,156	7,739	9,527	8,085	20,167	19,058	3,142	3,846	6,130

[1] Boat data for 1993 from the MAF 1993 vessel survey. Boat data for 1994 from 1994 beach/boat count as reported in B.G. Thompson, *Cost and Earnings Survey for the Oman Traditional Fishery, March 31, 1995.*

[2] Estimates based on fishermen data from the MAF 1993 vessel survey. Estimated as average fishermen per boat type over all regions, times number of boats for each type in each region, summed over types of boat.

V. IMPACT OF IMPLEMENTATION

A. Unilateral Implementation

If the selected management options are fully and successfully implemented only in the Sultanate of Oman, and other countries that may be fishing on the kingfish stock continue to fish at present levels, then the costs and benefits summarized in Table 2 are projected to occur, given average economic and environmental conditions. The principal costs and benefits, and timing of occurrence are:

- a decrease in catch of about 24% (84 mt based on 1993/94 season) for Musandam and 26% (161 mt) for Batinah during the first year of restrictions because of the predominance of small fish (<74 cm) in their catch.

- landings in other areas would be reduced about 6% and overall landings would be reduced about 11% in the first year.

- during year two and beyond, Batinah and Musandam would experience only small increases in catch of 3% and 5%, respectively; the greatest benefactors would be Muscat, Sharqiyah, and Al Wusta, where catches would increase on the order of 35%.

- an overall gain of 27% in landings over the base year (an increase of over 1,000 mt, with an exvessel value of about RO 1,000,000 over the 1993/94 season).

There are other impacts on the fishery that could not be quantified with existing information. These include:

- economic loss of use of smaller mesh nets

- economic costs of changing to alternative fisheries

- biological, economic and social impacts of redirected effort on other fisheries

- expected effect on catch rates and fishing participation

The Kingfish FMP estimated that 450 active kingfish boats land the bulk of the kingfish catch. If these boats average 1,000 m of net each, then total losses of smaller mesh nets by active kingfish boats would be less than 450,000 m of net, since some of the nets would exceed the proposed minimum mesh size. Some of the smaller mesh nets could be used in alternative fisheries, thus reducing both the loss of existing nets and the costs of changing to other fisheries. The redirected effort would increase competition in alternative fisheries, such as those for jacks, bluefish and other small pelagics, and increase pressure on those stocks.

If the number of active vessels in the kingfish fishery remains the same during the second year after implementation, then catch rates would be expected to increase; by as much as 36% in some areas. Because there are approximately 9,000 fishing boats in the Sultanate (see Table 1), it is likely that some of them will be attracted to the kingfish fishery and effort will increase up to the point where average costs of entering the fishery equal the average returns. This is likely to be a level of effort where catch rates are only slightly above pre-regulation levels. Total landings will be higher, but will be shared among more boats.

Unilateral implementation of the proposed management measures will result in an increase in the catch of kingfish by Omani fishermen. Modeling work by Dudley, *et. al* (1992) shows that the benefits of protecting young kingfish in the northern Gulf of Oman will directly benefit those fishermen who traditionally make catches of larger fish in southern waters. This occurs because fish less than 74 cm will grow as they move south, ultimately increasing the yield of

larger fish. Even if the fishing effort of the UAE and Yemen increases in response to more large fish, the fishermen of Oman will still land larger catches than they would have in the absence of any fishing restrictions.

Table 2. Analysis of management measure: minimum 14.6 cm (5.75 inch) stretched mesh nets with maximum headline length of 112 m for kingfish fishing in all regions, throughout the year. Boats less than 10 m may fish nets with a combined length up to 560 m: boats greater than 10 m may fish nets with a combined length up to 990 m.

Region	1993/94 Jul-Jun landings (mt)	Percent change in Jul-Jun landings[1]	Change in first year landings[2] (mt)	Second year landings[3] (mt)	Percent change from 1993/94 landings[1]	Increase in second year landings[4] (mt)	Annual Value of Increase RO
Musandam	349	-24%	-84	366	5%	17	16,150
Batinah	625	-26%	-161	644	3%	19	18,050
Muscat	1,122	-7%	-80	1,503	34%	381	361,950
Sharqiyah	1,164	-6%	-71	1,571	35%	407	386,650
Al Wusta	466	-6%	-29	634	36%	168	159,600
Dhofar	90	-6%	-6	122	36%	32	30,400
Total	3,816	-11%	-431	4,840	27%	1,024	972,800

[1] Percentages calculated from estimated changes in landings, and rounded to nearest whole number.

[2] No gains (only losses) are assumed to occur during the first year of implementation.

[3] Reflects changes from the 1993/94 season landings.

[4] A gain of 1,024 mt (27%) over the 1993/94 landings is assumed to occur in the second and succeeding years due to reduction in growth overfishing resulting from increased mesh size.

B. Implementation with International Cooperation

If the population of kingfish in Omani waters could be considered a genetically and/or geographically distinct population that is self-sustaining, then management of the stock would be simplified because all changes caused by fishing effort could be attributed to the Omani fishery. However, it seems likely that the countries of the UAE, Oman, and, to a lesser extent, Yemen are all fishing on the same population of kingfish (see further discussion in Section IX, Supporting Information.) Although catches in Oman are expected to increase with unilateral implementation of kingfish management measures, implementation of similar fishing restrictions in neighboring countries would enhance the benefits of management.

It is more important to establish cooperative management efforts with the UAE than with Yemen. As the population of kingfish move south along the coast of Oman, they are constantly growing and being fished upon by Omani fishermen. Fewer fish reach the Yemen coast (catches of kingfish at Dhofar have always been the smallest of all the regions of Oman) and those large fish that do reach Yemen would not be protected by implementation of the proposed mesh size restriction. In contrast, the UAE is known to land considerable amounts of small kingfish (20-30 cm) in the Arabian Gulf (Dudley final report) where much of the spawning seems to occur. Because the UAE also borders on the northern Gulf of Oman, it is likely that significant catches of small kingfish are made there as well. Enlisting the cooperation of the UAE in adopting similar fishing restrictions should contribute further to an increased catch of kingfish, both within Oman and UAE waters. Information on UAE catch, effort and capacity is not available to quantify the amount of that contribution.

VI. METHOD AND COST OF ENFORCEMENT

Table 3 summarizes the rules necessary to implement the intent of the selected management option. The proposed rules are:

Rule 1. It is illegal for persons on a boat to possess kingfish together with gill nets less than 14.6 cm stre... nesh and/or with headline length greater than 112 m.

Rule 2. It is illegal for persons in the Sultanate of Oman to possess kingfish of less than 74 cm fork length.

Rule 3. It is illegal for boats less than 10 m in length to fish nets for kingfish with combined headline lengths greater than 560 m; and it is illegal for boats greater than 10 m in length to fish nets for kingfish with combined headline lengths greater than 990 m.

All three of these rules must be enforced, fully and simultaneously, to achieve the projected benefits.

Enforcement efforts will be necessary both onshore and at sea, as some rules can only be effectively enforced at sea. Generally, enforcement efforts would be concentrated on those areas and times where the greatest number of infractions are likely to occur; namely in Musandam, Batinah and Muscat during the September to April season.

The enforcement program should involve a formal working relationship with the Royal Oman Police (ROP) and the Royal Oman Navy (RON), and should consist of teams working onshore and at sea. Ministry of Agriculture and Fisheries (MAF) staff are required in the enforcement activity to provide fisheries expertise and interpret the regulations. Twelve MAF staff would be required, to be teamed with 12 ROP and 12 RON personnel in six onshore and six at-sea enforcement teams. Each onshore team would include one MAF and one ROP staff. Each at-sea team would include one MAF, one ROP and one RON staff. The ROP staff are required to provide enforcement and arrest authority. The RON staff are required as boat

captains and crew on the at-sea teams to provide boat handling and seamanship ability. The costs presented in Table 3 are estimated start-up and operating costs for staff and equipment of the MAF, and estimated salary costs for the ROP and RON personnel. Equipment costs are for six four-wheel drive vehicles and six boats. The size of the boats deployed in each region will vary depending on local sea conditions, distance to the fishing grounds and the availability of harbors or the necessity to launch from the beach. Boats should be maneuverable and small enough to come alongside fishing boats and nets; fast enough to reach the fishing grounds and return quickly; and seaworthy enough to safely stay at sea with the fishing vessels in the area. However, the boat would not have to endure conditions too rough to fish, as enforcement would not be required when fishing does not occur. Details of the enforcement program are presented in the Appendix.

Table 3. Evaluation of rules to implement the intent of the chosen management measure.

Rules to enforce	Evaluation Criteria						
	Enforcement Effectiveness[1]		Industry Acceptance[1]	Enforcement Costs[2] (RO/year)		Lead Time to Implement (months)	Overall Rank/ Priority[3]
	Onshore	At Sea		Onshore	At Sea		
1. Prohibit possession by persons on a boat, of kingfish together with gill nets less than 14.6 cm stretch mesh and/or with headline greater than 112 m.	6	8	4	119,000	234,000	6	1
2. Prohibit possession of kingfish less than 74 cm fork length.	8	8	4			3	1
3. Prohibit boats < 10 m to fish nets for kingfish with combined headline lengths > 560 m; and Prohibit boats ≥ 10 m to fish nets for kingfish with combined headline length > 990 m.	1	5	7	Not Applicable		6	2

[1] On a scale of 1 to 10, with 1 representing a completely unworkable situation, and 10 representing a completely successful situation.

[2] Operating costs total RO 353,000 per year. Start-up costs of RO 277,000 are additional. See enforcement project proposal in Appendix for details of cost estimation. Enforcement effort would be concentrated 67% in the Musandam, Batinah and Muscat regions, and 33% in the Sharqiyah and Al Wusta regions.

[3] On a scale of 1 = high priority; 2 = medium priority; and 3 = low priority.

One onshore and one at-sea team each would be deployed in the Musandam, Muscat, Sharqiyah and Al Wusta regions. Two onshore and two at-sea teams would be deployed in the Batinah region. Onshore teams would randomly observe boats at landing sites for undersize mesh nets and possession of kingfish, and for possession of undersize kingfish. At-sea teams would make random checks of boats at sea, mostly at night, for possession of undersize nets and kingfish, possession of undersize kingfish, and for fishing more than the allowed amount of net for kingfish. Activity would be concentrated during the kingfish season from September through April, and teams would operate away from headquarters for extended periods.

This program represents the first step in establishing an effective enforcement regime, that is, verifying infractions of the law. The next step involves penalties for infractions, and these must be determined and established by the competent authorities in Oman.

VII. CONTINUING INFORMATION NEEDS

A. Cooperative Studies with the UAE

Much work needs to be done to better understand the spawning and migratory patterns of the kingfish population that is fished upon by both Oman and the UAE. While fishery data from Oman is being constantly improved, almost nothing has been documented regarding catch and effort by the UAE fishermen. It is important to the future fisheries of both countries that cooperative research and management programs be established. Collective efforts should focus on:

1. Kingfish Fishery

1) Develop a joint kingfish fishery management plan with the UAE.

2) Document the size of the kingfish fishery in the UAE, including the number of fishermen, the number of boats, and gear used when fishing on kingfish.

3) Gather information on the kingfish catch in the UAE, including length-frequency data. Establish the areas where catches are made.

2. Ecology

1) Conduct joint studies, utilizing electrophoretic or meristic techniques, to determine if different stocks of kingfish occupy the Arabian Gulf during spawning. Determine whether the population of *S. commerson* along the east coast of the Gulf of Oman and the Arabian Sea are genetically distinct from those along the western coast.

2) Icthyoplankton surveys should be conducted in the Arabian Gulf and in the Gulf of Oman to further establish spawning patterns both seasonally and spatially.

3) Mark-recapture studies would also provide information about migratory behavior, as well as provide estimates of fishing mortality independent of length data.

B. Studies by Oman

1. Kingfish Fishery and Stock Assessment

1) Conduct survey to determine sizes of gill nets used by the kingfish fishery and other fisheries which may use similar size mesh. Carry out gill net selectivity studies to assist in establishing a more comprehensive data base on catch and effort.

2) Verify the adequacy of the length-frequency data collection program. Stratified sampling should be continued at all major landing areas and during seasons when catches are greatest.

3) Previous studies of growth based on otolith studies were inconclusive. Further work needs to be done to confirm length at age. Data is needed from a wider range of sizes to better define the growth function.

4) Determine mortality rates from fishing and natural causes.

5) Pursue the use of catch and effort data to establish MSY (surplus production models).

2. Ecology

1) Conduct a general survey of icthyoplankton in Omani waters to delineate areas where kingfish may be spawning. Carry out a more detailed study in Masirah Bay. Determine whether this represents a significant source of recruitment to the Oman kingfish fishery using mark-recapture methods.

2) Carry out studies (electrophoretic or DNA) along the coast of Oman to help resolve the issue of stock mixing.

3) Conduct a study of predator-prey interactions (what do kingfish eat and what eats them, especially at egg/larvae/juvenile stage) to aid in the prediction of larval recruitment success.

VIII. MANAGEMENT MEASURES NEEDED IN THE FUTURE

Barring unforeseen success in recruitment, rebuilding the kingfish population to historical levels (10,000 mt) will be a slow process. A key to long-term success will be a resolution of the stock issue and the cooperation of those countries who impact on the Oman kingfish fishery. It may ultimately be necessary to implement more durable reductions in fishing effort such as limiting the number of kingfish fishing boats in the fishery or setting a maximum annual harvest for kingfish.

Future management actions directed toward the kingfish fishery will be based on an iterative process. Any population of fish rarely responds in a predictable fashion over a period of time. The fishery management process should be considered a dynamic one, and will need the capability to react in response to planned and unplanned changes in the fishery.

In developing the Kingfish FMP and this amendment, Chemonics' staff working under the Oman Fisheries Development and Management Project (FDMP) served as the secretariat to the Kingfish Committee and the Kingfish Task Force. Chemonics' staff served to focus, document and implement the policy directions given by the Committee and Task Force, and developed the original Kingfish FMP and this amendment. With the termination of the OAJC and the FDMP, the Directorate General for Fisheries Resources (DGFR) lacks a mechanism to focus management efforts, develop needed documentation and coordinate the policy decisions required for effective management. Such a mechanism needs to be created as a separate office within the DGFR, along the lines discussed by Moore and Dorr (1994) in their report on planning and administration for fishery management.

The fishery management planning process needs to include a structured mechanism for obtaining the opinions and advice of fishermen at an early stage. For each management plan under development, an advisory panel of fishermen and other members of the fishing industry should be established to advise the plan developers and policy makers on the nature of the problems in the fishery, the feasibility of proposed management measures, and the effectiveness of management implementation.

IX. SUPPORTING INFORMATION

A. Stock Differentiation

An important consideration in the management of kingfish is the degree to which the population in Omani waters may be considered a genetically and/or geographically distinct population that is self-sustaining. Evidence of this would simplify management of the stock because all changes caused by fishing effort could be attributed to the Omani fishery. However, this does not seem to be the case. Studies of genetic differences among kingfish populations, as reported in the Kingfish FMP, showed that populations in Omani waters were closely related to those from the UAE (Arabian Gulf). Comparisons with populations from Djibouti revealed greater genetic differences. Thus, stocks of kingfish along the coast of Oman are probably shared with the UAE, and perhaps Yemen to a lesser extent, and any management program will need to consider fishing pressure exerted by those countries.

There is some evidence to suggest that there may also be a resident population of kingfish in Omani waters. The kingfish FMP reported differences in genetic structure of kingfish sampled five months apart at Masirah Island. Hirai and Abdessalaam (undated) argued that length-frequency studies support the existence of two populations of kingfish in Omani waters; both migratory but at alternate times. Dudley and Aghanashinikar (1989) observed that kingfish from 60 to 80 cm were found at Musandam but fish of this size were missing from collections made at Mutrah at the same time. They commented on the possibility that some of the fish in

the Musandam area were from different sources of *S. commerson* than those found at Mutrah. Recent studies of icthyoplankton distribution by Thangaraja (Personal Communication, 1996) showed kingfish spawning near Masirah Island. He has postulated that the resulting juveniles may be moving into the Musandam area during September to feed on aggregations of sardines. The significance of this spawning needs to be established; not only as a contributor to the kingfish population but also because of the potential for confounding model results based on the assumption that all juveniles landed in northern Omani waters are moving south out of the Arabian Gulf.

Another concern is that kingfish stocks are also shared by countries bordering the eastern Gulf of Oman and the Arabian Sea such as Iran, Pakistan, and India. There are arguments for and against a common stock theory: 1) shared stock. Under this scenario, a single population of fish would move south out of the Gulf after completion of spawning. The population would split, with one segment following the eastern coast of the Gulf of Oman and the other the western coast. This choice may be made based on unknown hydrological or ecological factors. However, under this scenario, one would have expected a decline in the landings of Iran and India in response to the large catch of Oman during 1988 and 1989. This was not reflected in the landings as reported by those countries; 2) separate stocks. This requires that there are two distinct populations of kingfish migrating south out of the Arabian Gulf. One population migrates along the west Gulf coast and the other along the east Gulf coast. These populations form the basis of two separate fisheries. Once the populations have diverged, it is unlikely from an ecological perspective that any exchange occurs across the Gulf of Oman. In order for two distinct populations to exist, however, kingfish present in the Arabian Gulf would need to maintain genetic and reproductive isolation during spawning. This is feasible. The distance between the tip of Oman and the Iranian coast is almost 70 km. Because the kingfish is a coastal migrator, this distance could act as an effective barrier. Populations of kingfish moving into the Arabian Gulf from Iran would maintain their separation from the Omani stock. The result could be the establishment of two different spawning areas meeting the requirement of genetic and reproductive isolation. This interpretation is consistent with the reported landings of east coast countries which maintained or increased their catch during periods when landings in Oman were peaking and declining.

B. Status of Kingfish Fisheries in Oman, UAE, and Yemen

The Omani kingfish fishery fits the description (Laevastu and Favorite, 1988) of a collapsed stock, especially during 1991-1994: few age classes in the exploitable population, heavy fishing combined with low recruitment, and a long series of poor recruitment years. Studies of MSY from 1988 through 1993 (Gubsch, 1995) indicated that the level of effort needed to sustain the MSY was exceeded each year by 41 to 54 percent.

There is some evidence of recovery of the Omani kingfish fishery during 1995. Statistics indicate that the catch was more than 6,100 mt, or an increase of 61 percent above that reported for 1994 landings. While the analysis of catch and effort for 1995 has not been completed, it is probable that this increase is attributable to improved recruitment.

The pattern of catch of kingfish reported by the UAE and Yemen is not consistent with that reported for Oman. Catches by those countries were almost flat from 1984 through 1993, and do not reflect the spike experienced by Oman in 1987 and 1988. Barring gear saturation, or the presence of a second population of kingfish in Omani waters, the most probable reason for this disparity is faulty data. Almost nothing is known about the fisheries of the UAE and Yemen, or how their data is collected. This should be a study priority in the establishment of cooperative programs.

C. Importance of Recruitment

Increased catch for 1995 is probably due to improved recruitment success. This points up that the prediction of catch expected from the adoption of management efforts may be significantly compromised by factors other than fishing intensity. The role of biological and non-biological factors in the success of recruitment is well known. Deleterious changes in long or short term temperature regimes, increased predation rates, or decreases in spawner biomass are some of the reasons for continued recruitment failure. Most species do not have successful recruitment every year, and in fact, commonly experience recruitment failure. Monthly recruitment estimated by model studies (VPAIII-ELEFAN) showed that recruitment during 1988 was four times greater than during 1990-1992 (Gubsch, 1995). There has not been a good recruitment year in the Omani kingfish fishery since 1985. Because of the pressure maintained on the pre-recruits and adult population, recruitment has become of critical importance. Gubsch (1995) calculated the effect of doubling the recruitment over that observed for 1993 with fishing effort remaining constant at the 1993 level. Under this scenario, the yield was predicted to more than double. However, because the kingfish stock is at such a low level, it may take successive years of good recruitment before the population is restored to historic levels.

A successful recruitment year after implementation of the management measure should not result in termination of the measure, especially before the stock has fully recovered. Continuation of the mesh restriction would help maintain higher recruitment of juveniles into the fishery, resulting in a better representation of year classes in the catch.

D. Effectiveness of Management Implemented Within Oman Only

Modeling work by Dudley, *et al.* (1992) predicts that the benefits of protecting young kingfish in the northern Gulf of Oman will ultimately accrue to fishermen who land larger fish. These catches generally occur in the southern regions of Oman. Preliminary surveys (Abdessalaam, Personal Communication, 1996) of the UAE catch at Dubai indicate that as much as 85 percent of the kingfish landings are juveniles. This would suggest that most of the fish which reach sexual maturity (74 cm) will, ultimately, be caught by Omani and not UAE fishermen. Catches by the UAE have been reported as constant for several years and did not appear to change during the peak years of catch experienced by Oman. This implies that UAE fishing effort also has been constant. To the extent that UAE fishing effort remains unchanged, the benefits of increased catch should be realized mostly by Omani fishermen. Even if the fishing effort of the UAE increases in response to more fish, Oman's catch will still be larger than it would have been in the absence of any management measures.

E. Cooperative Management Among Involved Countries

Data suggest that it is more important to establish cooperative management efforts with the UAE than with Yemen. As the population of kingfish move south along the coast of Oman, they grow and are continually fished upon by Omani fishermen. Fewer large fish reach the Yemen coast (catches of kingfish at Dhofar are the smallest of all regions in Oman) and those large fish that do would not be protected by implementation of a mesh size restriction. Thus, it seems to make little sense to enlist their cooperation in adopting the proposed management measures. In contrast, the UAE is thought to land large numbers of small kingfish (20-30 cm) in the Arabian Gulf where much of the spawning seems to occur. Since the UAE also borders on the northern Gulf of Oman, it is probable that significant catches of small kingfish are being made there as well. It has already been stated that catches of kingfish in Omani waters would increase even in the absence of any combined management effort. However, enlisting the cooperation of the UAE in adopting the management measures should improve the chances of an increased catch of kingfish by Omani fishermen. It would also enhance the ability of both countries to achieve lasting success in the restoration of the kingfish population.

F. Optimum Rate of Recovery

Populations of pelagic fishes have been known to increase their annual biomass by an average of 38 percent during the recovery phase from a depleted state. It is impossible to predict whether the Oman kingfish population will ever achieve this recovery rate. Stock recovery from a collapsed state is probably not achievable by implementation of management efforts alone. Factors other than fishing effort which affect recovery include 1) predation mortality on larvae and juveniles, 2) natural (senescent) mortality, 3) recruitment to the exploitable stock, 4) biomass growth rate, and 5) immigration and emigration. Successive years of high recruitment are probably the single most important component in restoration of the kingfish population. Management measures need to be continued during periods of higher recruitment in order that gains in population size may be maintained.

G. Establishment of a Long-term Stock Assessment Program

Rational fisheries management requires detailed knowledge of 1) the magnitude of resource, 2) natural fluctuations of the resource and their causes, 3) maximum sustained yield, 4) ecology of the fish, including reproduction, growth, and migration, and 5) economic and social forces that influence the operation of a fishery. Limited studies to support fisheries management goals have been conducted in Oman. These studies have often been done by selecting a model or assessment method which could utilize existing data. While practical, this approach is warranted only when making a preliminary assessment of resources. It reflects an opportunistic use of data, the product of which may not satisfy the needs of long-range stock assessment. Oman needs to establish a stock assessment program which will improve their predictive capability. This will require the timely identification of appropriate models or techniques to allow for the development of data acquisition programs.

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N. B. Additional sources listed in the original Kingfish FMP are incorporated here by reference.

Appendix 1

PROJECT: KINGFISH REGULATIONS ENFORCEMENT

1. **Project Objective** To obtain compliance with kingfish fishery regulations.

2. **Project Description** This project will create the capability to enforce kingfish regulations by establishing an enforcement program involving a formal working relationship with the Royal Oman Police (ROP) and the Royal Oman Navy (RON). The enforcement program will consist of teams working onshore and at sea. Twelve Ministry of Agriculture and Fisheries (MAF) enforcement and surveillance staff will be required for this project, to be teamed with 12 ROP and 12 RON personnel in six onshore and six at-sea enforcement teams. Each onshore team of two people will include one MAF and one ROP staff. Each at-sea team of four people will include one MAF, one ROP and two RON staff, and will operate eight months per year from September through April. The MAF staff are required on the teams to provide fisheries expertise and interpret the regulations. The ROP staff are required to provide enforcement and arrest authority. The RON staff are required on the at-sea teams as boat captain and crew to provide boat handling and seamanship ability.

The teams will be deployed so that enforcement effort is concentrated where the most infractions are expected. Initially, one onshore and one at-sea team each will be deployed in the Musandam, Muscat, Sharqiyah and Al Wusta regions. Two onshore and two at-sea teams will be deployed in the Batinah region. Team deployment will be reviewed annually to maintain the most effective distribution of enforcement effort. Onshore teams will randomly observe boats at landing sites for undersize mesh nets and possession of kingfish, and for possession of undersize kingfish. At-sea teams will make random checks of boats at sea, mostly at night, for possession of undersize nets and kingfish, possession of undersize kingfish, and for fishing more than the allowed amount of net for kingfish. Activity will be concentrated during the kingfish season from September through April, and teams will operate away from their headquarters for extended periods.

Equipment will consist of six, four-wheel drive vehicles for the onshore teams and six, seven to nine meter boats with twin outboards, all with VHF radios. Boat size will vary by region according to the local sea conditions, availability of harbors, need to launch the boats from the beach, and the distance to the fishing grounds. The boats should be fast enough to reach the fishing grounds and return quickly, maneuverable enough to bring alongside fishing boats and nets, and seaworthy enough to remain at sea with most of the fishing boats in the area. If the weather becomes too bad to fish, then there is no need for the enforcement boat to go to sea.

3. **Project Operating Locations (Headquarters)** Musandam (Bukha), Batinah (Shinas and Sohar or Barka), Muscat (Mutrah or Sidab), Sharqiyah (Sur), Al Wusta (Duqm).

PROJECT: KINGFISH REGULATIONS ENFORCEMENT - Continued

4. Project Benefits The proposed kingfish regulations, if effectively enforced, should create an increase in annual landings valued at RO 978,500. An effective enforcement effort consisting of surveillance and enforcement by MAF personnel combined with ROP and RON enforcement activity will reduce illegal landings and promote conservation. This will increase the yield from available resources and improve income in the fisheries. As an added benefit, implementation of an effective enforcement program for kingfish regulations can serve as an example on which to model enforcement programs for other fisheries, as well as provide the initial capability to enforce additional regulations as needed.

5. Project Costs and Implementation Schedule

- MAF Start-up Cost: RO 277,000
- Annual Operating Cost: MAF RO 245,000
  ROP RO 60,000
  RON RO 48,000

5.1 Start-up Costs

Item	Number	Unit Cost (RO)	Total Item Cost (RO)	Implementation Time (Weeks)
Vehicle (4WD)	6	10,000	60,000	12
Boat (7-9m, 2 engines)[1]	6	30,000	180,000	12
VHF radio	18	[2]	12,000	12
Other expense [3]	NA [4]	NA [4]	25,000	NA
Total			277,000	

[1] Actual boat size based on local conditions. Estimated costs based on an 8 m center console planing hull with twin 200 hp outboards plus gear and navigation equipment.
[2] Six base stations @ 1,000, 12 mobile units @300 each, and 12 hand held @ 200 each.
[3] Contingency fund of 10% of capital costs.
[4] NA = Not Applicable.

PROJECT: KINGFISH REGULATIONS ENFORCEMENT - Continued

5.2 Operating Costs

Item	Agency		
	MAF (RO)	ROP (RO)	RON (RO)
Salary (18@6,000/yr, 18@4,000/yr)[1]	72,000	60,000	48,000
Vehicle operation and maintenance[2]	148,000	NA [3]	NA [3]
Supplies and equipment	5,000	NA [3]	NA [3]
Other expense[4]	20,000	NA [3]	NA [3]
Total	245,000	60,000	48,000

[1] Includes fringe benefits and allowances. Six ROP and 12 RON staff on at-sea teams costed for 8 months/year.
[2] Includes maintenance/depreciation allowance of 20% of purchase cost per year. Vehicle operating costs estimated at RO 15/day for 260 days/year. Boat operating costs estimated at RO 100/day for 16 days per month for eight months per year.
[3] NA = Not Applicable.
[4] Includes travel, administrative and contingency expenses.

If salaries are excluded, then annual operating costs would be RO 173,000. This cost is balanced against an expected increase in the average annual exvessel value of kingfish landings of RO 972,800. The public cost of achieving the increase is only 17 percent of the value of the increase. Viewed a different way, the public investment in kingfish regulations enforcement yields over 500 percent return in exvessel value of increased kingfish landings

6. Documentation and Other Sources of Information This project used cost estimates for enforcement and surveillance activities developed for the *Draft Fifth Five-Year Fisheries Sector Development Plan* of the Directorate General of Fisheries, 1994, and information on fish landing sites from the *Cost and Earnings Survey for the Oman Traditional Fishery Manual* by B. G. Thompson, March 31, 1995, Chemonics, Inc..