

Project Title: Sustainability Assessment of Small Pelagic Fisheries in the Sultanate of Oman: A Multi-Model Length-Based and Catch-Based Approach

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Duration: 24 Months

Target Species: Indian Oil Sardine (*Sardinella longiceps*), Indian Mackerel (*Rastrelliger kanagurta*), Anchovies (*Encrasicholina* spp.), Indian Scad (*Decapterus russelli*), and Tiger Perch (*Terapon jarbua*).

*Note- The list of species can be amended according to updates to the species composition of the fishmeal.

1. Introduction and Background

Small pelagic fish are the backbone of Oman's marine fisheries, making up a sizable portion of all landings and being essential to both the local economy and food security. In addition to being a direct source of protein, species like the Indian Oil Sardine (*Sardinella longiceps*) are essential to fishmeal and the developing value-added processing sectors. Large-scale canning plants and other recent investments in the fishing industry highlight the resources' increasing economic significance.

Small pelagic stocks, however, are particularly vulnerable to environmental variations and exploitation. In order to avert population collapse and guarantee long-term sustainability, there is an urgent need for updated, thorough stock assessments given the increased fishing effort seen along the Omani beaches. In light of the existing data availability for these species, this project suggests a thorough evaluation using data-limited techniques.

2. Objectives

This project's main objective is to assess the state of important small pelagic fish stocks in Omani waters and offer management recommendations based on science. The particular goals are:

1. To use length-frequency data to estimate important population parameters (growth, death, and maturity) for the target species.
2. To use length-based reference points and catch-based models to ascertain the current exploitation rates and stock state (e.g., overfished/undergoing overfishing).

3. To calculate biological reference points (such as MSY , B/B_{MSY} , and F/F_{MSY}) in order to inform sustainable harvesting practices.
4. To map the seasonal and geographical distribution of nursery and spawning grounds in order to guide spatial management strategies.

3. Expected Outcomes

This project will deliver:

- A database of updated population parameters (L_{∞} , K , M , L_m , L_c) for the target species.
- A comprehensive stock status report for the the Arabian Sea, identifying stocks that are healthy, overexploited, or collapsed.
- Management recommendations, including catch limits, seasonal closures, or gear modifications, presented to the Ministry of Agriculture, Fisheries and Water Resources (MAFWR).

Methodological Framework

This framework outlines a stepwise approach to assess small pelagic stocks, integrating data collection with analytical models. This approach is consistent with recent studies conducted in Oman on both small pelagics and other commercially important species.

1. Sampling Strategy and Data Collection

Effective assessment relies on high-quality, representative data.

- **Sampling Sites:** Samples will be collected from major landing centers of the Arabian Seaside (e.g., Duqm and Salalah) coasts to capture potential stock differentiation.
- **Frequency:** Monthly sampling over a 24-month period to account for seasonal growth patterns and spawning cycles influenced by the Southwest and Northeast monsoons.
- **Data to be Collected:**
 - **Length and Weight:** Total length (TL) and fork length (FL) to the nearest millimeter, and total weight (TW) to the nearest gram.
 - **Length-Frequency Data (LFD):** A minimum of 100-200 individuals per species per month to construct robust length-frequency distributions.
 - **Biological Data:** Macroscopic staging of gonads to determine spawning season and length at first maturity (L_m). Collection of otoliths for age validation to support growth models.

- **Catch and Effort Data:** Collection of nominal catch (tonnes) and fishing effort (e.g., number of boat trips, days at sea) from landing site surveys and MAFWR statistical bulletins.

2. Estimation of Population Parameters

- **Growth Parameters:** The von Bertalanffy Growth Function (VBGF) parameters (L_{∞} and K) will be estimated using the ELEFAN (Electronic Length Frequency Analysis) routine available in software packages like TropFishR or Length-based Bayesian biomass (LBB). Where possible, multi-model inference (e.g., comparing VBGF with Gompertz or Logistic models) will be used to select the best-fitting growth model, as demonstrated in recent studies in the region.
- **Mortality Rates:**
 - **Total Mortality (Z):** Estimated from length-converted catch curves, which plot the natural logarithm of the number of fish against their relative age.
 - **Natural Mortality (M):** Estimated using empirical formulas (e.g., Pauly's formula) that utilize growth parameters (L_{∞} , K) and mean environmental temperature.
 - **Fishing Mortality (F):** Calculated as the difference between total and natural mortality ($F = Z - M$). The current exploitation rate (E) is then derived as $E = F/Z$.

3. Stock Assessment Models

Given that small pelagic fisheries are often data-limited, a combination of methods will be used to triangulate results.

- **Length-Based Methods:**
 - **Yield per Recruit (Y/R) and Biomass per Recruit (B/R) Analysis:** Used to evaluate if the stock is growth-overfished. Reference points like $F_{0.1}$ and $F_{\max}$ will be estimated to guide fishing mortality targets.
 - **Length-Based Spawning Potential Ratio (LB-SPR):** This model estimates the spawning potential ratio (SPR) using length data and biological parameters (L_{∞} , M/K , L_m). An SPR of less than 40% typically indicates an overfished stock.
 - **Length at First Capture (L_c):** The length at which 50% of fish are vulnerable to the gear will be estimated and compared to L_m (length at maturity) to assess gear selectivity issues.
- **Catch-Based Methods:**

- **Catch-MSY (CMSY) Method:** This method will be applied to estimate Maximum Sustainable Yield (MSY), stock biomass (B), and fishing mortality relative to MSY-based reference points (B/B_{MSY} , F/F_{MSY}). It requires only time-series of catch data and prior information on stock resilience, making it ideal for data-poor contexts.
- **Surplus Production Models:** Where reliable CPUE (Catch Per Unit Effort) data is available, models like the Schaefer or Fox models will be fitted to estimate carrying capacity (K) and MSY.

4. Data Analysis Tools

- **Software:** Data analysis will be performed using R (specifically packages like tidyverse, TropFishR, LBB, and LBSPR) which are widely used in fisheries research.

5. Expected Outcomes and Management Recommendations

The integration of results from the above methods will allow for a triangulated assessment of stock status. Stocks will be classified according to their status (e.g., underfished, fully fished, overfished). Specific management advice will include:

- **Input Controls:** Recommendations for adjustments in fishing effort or modifications to gear mesh size to increase L_c to be at or above L_m .
- **Output Controls:** Science-based catch limits (TACs) aligned with MSY estimates.
- **Spatial/Temporal Closures:** Identification of spawning aggregations or nursery grounds (e.g., around Masirah Island or during specific monsoon periods) to recommend temporary fishing bans to protect juvenile and spawning fish.

6. Timeline (Gantt Chart Summary)

Activity	Months 1-3	Months 4-9	Months 10-15	Months 16-21	Months 22-24
Sampling & Data Collection					
Lab Analysis (LW, Otoliths, etc.)					
Parameter Estimation					
Stock Assessment Modeling					
Report Writing & Dissemination					

Budget: (for 24 Months)

Budget Category	Cost (OMR)	Notes
1. Personnel		
Principal Investigator (10% time)	7,200	24 months @ 300 OMR/month
Fisheries Biologist (2 field staff)	9,600	2 staff @ 200 OMR/month x 24 months
Subtotal Personnel	16,800	
2. Travel & Fieldwork		
Travel	2,000	Travel to the field sites
Subtotal Travel	2,000	
3. Equipment & Supplies		
Sampling Equipment	1,000	Measuring boards, scales, calipers, trays
Lab Consumables	1,000	Preservatives, vials, labels, dissection kits
Otolith Analysis Supplies	1,500	Microscopes slides, resins, cutting blades
Subtotal Equipment	3,500	
4. Other Costs		
Training Workshop	1,000	Stakeholder engagement, results dissemination
Report Printing & Publication	500	Final reports, management briefs
Contingency	1,000	Unforeseen expenses
Subtotal Other	2,500	
TOTAL PROJECT BUDGET	24,800	

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