Marine Policy 61 (2015) 23–32

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Enhance and advance: The benefits of recruitment enhancement in the case of the Iranian Kutum Fishery

Pezhman Alaei Borujeni [a], Stein Ivar Steinshamn [b,*], Sayed Abolghasem Mortazavi [a], Hasan Salehi [c]

[a] Department of Agricultural Economics, Tarbiat Modares University, P.O.Box: 14115-336, Tehran, Iran
[b] Department of Business and Management Science, Norwegian School of Economics, Helleveien 30, NO-5045 Bergen, Norway
[c] Iran Fisheries Organization, No. 236, West Fatemi Ave., P.O.Box: 1413636331, Tehran, Iran

ARTICLE INFO

Article history:
Received 9 January 2015
Received in revised form
23 June 2015
Accepted 23 June 2015
Available online 4 July 2015

Keywords:
Bioeconomic modelling
Age-Structured models
Enhancement programme
Fishing mortality
Kutum
Caspian Sea

ABSTRACT

A bioeconomic age-structured model is used to analyse the profitability of the recruitment enhancement programme for Kutum *Rutilus frisii kutum* (Kamensky 1901) fishing in Iranian coastal waters of the Caspian Sea. This programme has been in place since 1982. The net present value from the fishing activity is calculated in view of the effects of the enhancement programme on recruitment, catch and fishing activity costs. The results show a significant positive effect of the programme on profitability. Further, the effect of fishing mortality adjustment, as a management tool, on the profitability is also evaluated. It is shown that a reduction in fishing mortality causes a consequent increase of the NPV from the fishing activity. The enhancement programme can be considered a valuable addition to proper management for increasing economic performance when combined with appropriate management adjustments; in our case: reduction of the fishing mortality.

1. Introduction

The objective of this paper is to analyse the profitability of Kutum *Rutilus frisii kutum* (Kamensky 1901) fishing in the Iranian coast of the Caspian Sea. Kutum is a fish of the family *Cyprinidae* and endemic to the Caspian Sea, north of Iran. The Iranian Kutum population has been dwindling for four decades, from 1940s to the 1980s, due to overfishing and loss of natural spawning grounds. In the early 1980s, these stocks have improved through an enhancement programme by releasing fingerlings. Despite the costly nature of this programme, it has played a significant role in reviving the stock and increasing the yield [1]. A cost benefit analysis of the enhancement programme for the Kutum fishery for different fishing mortality levels, based on an age-structured bioeconomic model, will be undertaken.

Age-structured models can be used to separate and analyse a fishery into distinct age or size classes of cohorts [2]. This allows for greater understanding of the fishery, as harvesting often takes place on a small number of cohorts, and sizeable differences in the relative strengths of cohorts are important determinants that affect the total catch [3]. Bioeconomic age-structured models are used to develop estimates of optimal yield or harvest-per recruit relationships that depend on, among other things, fishing mortality, natural mortality and the age or size at which fish from a given cohort or age class become vulnerable to fishing. These models have recently been developed for general cases that represent not only uniformly distributed fish stocks, but also any degree of schooling and unevenly distributed fish [4].

Tahvonen (2009) derived both analytical and numerical results on optimal harvesting in a dynamic setting under various simplifying assumptions with age-structured models [5]. Tahvonen (2010) investigated the background and development of discrete time age-structured optimization models in fisheries economics [6]. Skonhoft et al. (2012) studied an age-structured model of a fishery and described the optimal harvesting policy when the fleet can choose different fishing gear with perfect and imperfect fishing selectivity [7].

The age-structured bioeconomic model in this paper is a fairly standard Beverton–Holt model that is used to evaluate the enhancement programme for Iranian Kutum. This model will be used to maximize the Net Present Value (NPV) of benefits from Kutum fishing in the presence of stock enhancement programme and thus to determine optimal policies. For that, we use the estimated yield

* Corresponding author.
E-mail addresses: alaei.pezhman@modares.ac.ir (P. Alaei Borujeni), stein.steinshamn@nhh.no (S.I. Steinshamn), samortazavi898@modares.ac.ir (S.A. Mortazavi), hsalehi_ir@yahoo.com (H. Salehi).

http://dx.doi.org/10.1016/j.marpol.2015.06.026
0308-597X/

and recruitment data to calculate the NPV under different levels of fishing mortality, applying two forms of stock–recruitment (S–R) relationships due to Ricker (1954) [8] and Beverton–Holt (1957) [9]. Data and information were collected from the annual reports of Kutum stock assessment, operated by the Iranian Fisheries Research Organization (IFRO).

The paper is organized as follows: Section 2 provides a background of stock enhancement and its contribution to fisheries management goals worldwide. In Section 3, a summary of the status of Kutum stock in the Caspian Sea, with regard to its declining stock in the past and recent improvements through the enhancement programme, is discussed. Section 4 gives an overview of bioeconomic age-structured models, as a basis for yield and recruitment calculation, which will be used to calculate the profitability of fishing activities. In Section 5, the bioeconomics of the Kutum fishing is analysed. This includes considering the effects of the enhancement programme as well as varying fishing mortality to find the optimal level. Conclusions and policy implications are presented in the final section.

2. Stock enhancement

Stock enhancement has been performed for a range of species various places around the world dating back to the 19th century. The first marine stock enhancement programmes in the United States started in the late 19th century in Massachusetts and Maine. For over 60 years, many millions of young cod, haddock, pollock and flounder were released annually in an effort to enhance wild populations. These programmes were stopped due to lack of measurable effect [10].

Systematic large-scale programmes for the release of fingerlings for stock replenishment and augmentation were not common until the 1970s. A modern pioneer country has been Japan. The Japanese programmes include around 80 species of marine fish, molluscs and crustaceans, of which the most important ones are scallops, prawns, sea bream and flounders [11].

Another pioneer has been Iran, which shares the fisheries resources of the Caspian Sea with four other states: Azerbaijan, Kazakhstan, Russia and Turkmenistan. Fisheries scientists in Iran release around 12 million juveniles of sturgeon species, which support the valuable caviar industry. In addition, state hatcheries release juvenile Bream, Kutum, Pike-Perch, and Caspian Trout, all of which support fisheries harvested by licensed coastal cooperatives [12].

Many different purposes and objectives for such programmes have been mentioned: stock conservation, stock augmentation, recreation and improving economic performance to mention a few. In this article, however, we concentrate mainly on the latter.

Although there has been written many studies about the biological and ecological aspects of stock enhancement and ocean ranching [13], relatively few studies have been made about the economic performance of such programmes. The most noticeable one is perhaps Hilborn (1998). He reviewed nine marine enhancement programmes and found that only one, the Japanese chum salmon programme, appeared to be a clear success. Other programmes, for example pink salmon in Alaska, chinook and coho salmon in the U.S. and Canada, lobster in the U.K. and France, cod in Norway, and Kemp's ridley sea turtle were clear failures. Other again lacked data or the conclusion was ambiguous [14]. Hermann (1993) performed another considerable analysis about sea ranching of salmon in Alaska, which indicated that expanding the enhancement programme for sockeye salmon and contracting for pink salmon have positive effects on future revenues generated to fishers [15].

However, the future may not be entirely bleak. Lorenzen et al. (2013) state that “The science base of marine restocking, stock enhancement, and sea ranching continues to advance rapidly and has now reached a point where it is becoming possible to assess the likely contribution of such approaches to fisheries management goals prior to major investments being undertaken and to design enhancement programmes effectively and responsibly where good potential is judged to exist” [16].

3. An overview of the Iranian Kutum Fishery

The Caspian Sea is quite remarkable as an immense ecosystem in ecological, biological and economic terms. It is a brackish lake with no outlets, lying to the east of the Caucasus Mountains and to the west of the vast steppe of Central Asia. It has shores in the five countries: Russia, Azerbaijan, Iran, Turkmenistan and Kazakhstan. One of the main features of this sea is its unique and valuable aquatic community that includes sturgeons and several bony fish species. In recent years, on the Iranian coast of the Caspian Sea, fishing cooperatives have exploited various types of bony fish, of which Kutum is the most popular and commercially important [17].

Kutum is a fish from brackish water habitats of the Caspian Sea and from its freshwater tributaries. The main distribution of Kutum belongs to the southern part of the sea. The highest density of Kutum fish was traditionally distributed between the Kura River in Azerbaijan and Sefidrood River in Iran [18]. Nevertheless, during the last three decades, after massive releasing of fingerlings along the Iranian coast of the Caspian Sea, its distribution has changed and its density on the Iranian southeastern coast of the sea has increased [19].

In recent years Kutum make up more than 60% of the total catch of bony fish on the Iranian coast of the Caspian Sea. As shown in Fig. 1, before the 1980s, the highest recorded catch was 5854 t in 1939. Later on, the stock declined and the catch reached its lowest point of approximately 350 t in the early 1980s [17,20]. This reduction was caused by over-fishing, decreasing water level in the Caspian Sea, agricultural, municipal and industrial emissions, over-exploitation of sands and sediments from coastal rivers and the Anzali Bay, and construction of bridges and dams that modify or block the natural spawning grounds [21–23].

The Iranian Fisheries Organization (IFO) started to revive the declining stock of Kutum by releasing fingerlings in the rivers in 1982. In the last three decades, a total of 4.62 billion fingerlings were released into the rivers and Anzali Bay, which had a significant positive effect in reviving reserves and increasing total yield [24]. At present, artificial breeding and restocking programmes represent the main method for maintaining and enhancing the Kutum population.

4. Bioeconomic modelling

An age-structured bioeconomic model is used to determine the optimum policy of maximizing fishing profits. For that, the dynamics of the Kutum population is analysed by determining the weight at each age class (W_i), each cohort's population (N_i) and each year's recruitment to the stock (R_t). This will allow us to determine the total yield for each year of the study period (Y_t).

The age-structured estimation of total yield will then be used to calculate the total revenue from harvesting which is a part of estimating the net present value of fishing activities. The second part of the profit function is the total cost, which includes the costs of harvesting and the costs of releasing fingerlings. Finally, the effects of implementing the enhancement programme and fishing