Analyzing the Catch rate of Green tiger shrimp (Penaeus semisulcatus) using some statistical uncertainty methods (Bushehr coastal waters)

Moslem Daliri*,1, Ehsan Kamrani2, Mehran Parsa1, S. Yousef Paighambari3 & Ali Nekuro1
1 Young Researchers and Elite Club, Bandar Abbas Branch, Islamic Azad University, Bandar Abbas, Iran.
2 Fisheries Department, Faculty of Marine and Atmospheric Sciences, Hormozgan University, Bandar Abbas, Iran.
3 Faculty of Fisheries and Environmental Science, Gorgan University of Agricultural Sciences and Natural Resources. Golestan, Iran.

* [E-mail: Moslem.daliri@yahoo.com]

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The objective of the present paper was to estimate the catch rate of Green tiger shrimp (P. semisulcatus) from Bushehr coastal water with some statistical uncertainty methods. Collection of data was performed during 94 hauls by C/V SHANAK. Fishing took place at three depths strata (stratum A: <10m depth, stratum B: 10-20m and stratum C: >20m). The non-parametric bootstrap method was utilized to estimate the catch rate (±Confidence interval) (kg. h⁻¹) of P. semisulcatus for each stratum. A randomization test was also used to compare the mean catch rate among three depth strata. The minimum and maximum catch rates (kg. h⁻¹) of P. semisulcatus was obtained between 4 - 8.8 for depth A, 6.8 – 8 for depth B and 2.7 – 5.1 for depth C (α=0.05). Results of the randomization test showed that there is no significance difference among the mean catch rate in three depth strata in Bushehr coastal water (P>0.05). Managing fisheries under uncertainty has become a top priority for fishery biologists around the world, and this paper is the first study on utilization of uncertainty in fisheries researches of the Iranian water of the Persian Gulf.

[Keywords: Green tiger shrimp, Uncertainty, Bootstrap, Randomization test, catch rate, Persian Gulf]

Introduction

Uncertainties are ubiquitous in fisheries. Yet despite an abundance of research attention on the subject, the profound impact of such uncertainties on the sustainability of fisheries seems to have been widely underestimated in the past. Recently, however, there has been a growing recognition of the need to allow for uncertainty not only quantitatively (for example, in setting catch quotas and fishing effort limits) but also qualitatively, in determining suitable characteristics of fishery management. Uncertainties in fisheries may be placed within three major categories: random fluctuations (noise) that are relatively well studied and well understood, uncertainties due to imprecise parameter estimates and unknown states of nature and fundamental structural uncertainties (reflecting ignorance about the nature of the fishery system) that are notably difficult to address. They have been applied to a variety of fishery topics, from biological dynamics and stock assessment studies to bio-economic modelling of stochastic fisheries.

Structural uncertainty is the most fundamental form of uncertainty, reflecting basic ignorance about the nature of the fishery system, its components, its dynamics and its inherent internal interactions. Other instances of structural uncertainty are spatial complexity (spatial heterogeneity, stock concentrations and migration patterns) and Fish–fish interactions (Multi-species interactions, and predator–prey effects).

Catch data from trawl surveys are used to derive abundance indices and biomass estimates for commercially important fish stocks. Catch per Unit of effort (CPUE) is often the main piece of information used in fisheries stock assessment. CPUE is usually assumed to be proportional to abundance and therefore included in the stock assessment as a relative index of abundance. Green tiger shrimp (Penaeus semisulcatus, De Haan, 1884) fishing is very common in the Persian Gulf (in Bushehr province) and has an important role from both an economic and a social aspect. Shrimp fishery, particularly of penaeid shrimps, has been carried out using a specially designed bottom trawl that is called shrimp-trawl in this region. Although some investigations have documented the fisheries of penaeid shrimps in Persian Gulf, no uncertainty analysis has been conducted on the catch rate and catch per unit of effort in the Persian Gulf.

This paper reviews some statistical uncertainty methods in the analysis of catch rate of Green tiger shrimp.
shrimp (*Penaeus semisulcatus*) in Bushehr water. These statistical methods have focused on modelling and assessing the effects of different strata and depths on catch rate of this species. No analytical models are currently used in the assessment of the Green tiger shrimp’s stock and catch rate, and in this paper we used a bootstrap method and randomization test to explore these aspects of the uncertainty in catch rate of Green tiger shrimp in Bushehr water.

**Materials and Methods**

The study area extended from longitude 50° 06’ to 52° 58’ E and latitude 27° 14’ to 30° 16’ N (Bushehr coastal water) and covers the fishing grounds of shrimp (Fig. 1). Sampling was performed by C/V SHANAK (an equipped outrigger bottom trawler to two trawl nets with a 31 m head line and a 40 mm and 50 mm mesh size (STR) in the cod-end and net body, respectively). Towing was averagely carried out between 1-2 hours at speeds of about 3 knots and depth was measured by a vertical FCV-667 echo-sounder (stratum A: <10m depth, stratum B: 10-20m and stratum C: >20m depth). After each haul (94 hauls), the total catches were unloaded on the deck and bycatch was separated from shrimp. Shrimp species were identified to the lowest taxonomic level and weighed14.

Fig. 1—Map of the Persian Gulf and location of sampling site.

The catch per hour (Kg. h⁻¹) was estimated for all hauls. Subsequently, the mean of catch rate (± CI) was calculated for each stratum (A, B and C) by Non-parametric bootstrap method as following steps 15:

- Generate 1000 independent bootstrap samples \(x_1, x_2, x_3, \ldots x_{1000}\), each consisting of \(n\) data values drawn randomly with replacement from the \(n\) values in the original samples (such as Table 1).

<table>
<thead>
<tr>
<th>Count</th>
<th>Original sample</th>
<th>Bootstrap samples</th>
<th>1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>3000</td>
<td>7.17</td>
<td>7.03</td>
<td>7.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7.22</td>
</tr>
</tbody>
</table>

- Calculate the bootstrap replicate of the parameter or statistic \(\hat{\Theta}_i\) for each of the 1000 bootstrap samples. The statistic must be a continues function of data:

\[
\hat{\Theta}_i = f(x_i)
\]

- Estimate the standard error \(se_\Theta\) of the parameter \(\Theta\) by calculating the standard deviation of the 1000 bootstrap replicates:

\[
se_\Theta = \sqrt{\frac{\sum(\hat{\Theta}_i - \bar{\Theta})^2}{1000 - 1}}
\]

Where \(\bar{\Theta}\) is the mean of the bootstrap replicates of \(\hat{\Theta}_i\), which is the bootstrap estimate of the statistic \(\Theta\):

\[
\hat{\Theta} = \frac{\sum \hat{\Theta}_i}{1000}
\]

- Confidence intervals around the parameter was obtained by following equation:

\[
CI = \Theta \pm t_{n-1,\alpha/2}se_\Theta
\]

Where \(\Theta\) is the sample parameter estimate, \(t_{n-1,\alpha/2}\) is the student’s \(t\) distribution value for \(n-1\) degrees of freedom (where \(n\) is the number of bootstrap replicates) and \(\alpha/2\) is the percentage confidence limits desired (\(\alpha=0.05\)).

A randomization test was used to compare the mean catch rate of *P. semisulcatus* in three depth strata. It shows that whether the observed data for each group represents a random sample from a single population (null hypothesis). Figure 2 indicates the algorithm for conducting a randomization test15:

Data analysis was done by Visual Basic for Applications (VBA) in Excel 2013.
Results

The frequency distribution of bootstrap replicate values is plotted in Figure 3. The minimum and maximum catch rates (kg. h⁻¹) of *P. semisulcatus* was obtained between 4 - 8.8 for depth A, 6.8 – 8 for depth B and 2.7 – 5.1 for depth C (Fig. 3).

The randomization test found that original mean difference occurred 610 (for group 1), 384 (for group 2) and 193 (for group 3) times out of one thousand. Thus, there is no significance difference among the mean catch rate (kg. h⁻¹) of *P. semisulcatus* in three depth strata in Bushehr water (P>0.05).

Table 2— Comparing the mean catch rate (kg. h⁻¹) of *P. semisulcatus* in three depth strata (ANOVA test) by Randomization test.

<table>
<thead>
<tr>
<th>Mean Catch rate (kg.h⁻¹)</th>
<th>Result of Randomization test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth A</td>
<td>1 A and B</td>
</tr>
<tr>
<td>Depth B</td>
<td>2 A and C</td>
</tr>
<tr>
<td>Depth C</td>
<td>3 B and C</td>
</tr>
</tbody>
</table>

Discussion

Results of this study have important implications in evaluating the catch rate of *P. semisulcatus* that were collected at different depth layers in fishing grounds of Bushehr province. Reportedly Paighambari and Daliri¹⁶, catch rate of Green tiger shrimp (in Bushehr water) was 17.68 kg. h⁻¹ in 2002. Subsequently, Shabani and Shadkami¹⁷ asserted that it was 4.35 kg. h⁻¹ in 2010. Whiles catch rate of the selected species at the present paper was averagely estimated 5.9 kg. h⁻¹. Because shrimps’ lifetime is short (have r strategy), it is important to have a continuous series of catch analysis during different times to an accurate shrimp stock assessment. Thus, results of the present paper could be helpful for accessing this purpose.

Also, results of this paper show that the catch rate of *P. semisulcatus* weren’t affected by depth, which is in agreement with reports of Daliri¹⁸ and Hosseini *et al.*¹⁹. Also, Moradi *et al.*³ and Parsa *et al.*²⁰ reported that there is not any positive correlation between catch rate of *P. semisulcatus* and various
depth layers. The similarity in ecological conditions at fishing season (summer season) is likely reason to lack of relationship between catch rates of green tiger shrimp and different depths of study area.

In other hand, Fatih Can et al. evaluated the catch rate of *P. semisulcatus* in two depth layers (<20 m and >20 m) in Iskenderun Bay (Mediterranean Sea, Turkey) during one year and their results indicated that the CPUE of *P. semisulcatus* in more than 20 m depth layer is higher than <20 m depth layer. The difference between these two researches could be due to time period and location of study. Although there are numerous researches about shrimp stock assessment (reports for opening fishing season) in Bushehr coastal water, but this paper is the first study on utilization of uncertainty in fisheries researches. Using statistical uncertainty methods is a new concept in fisheries researches and it is a relatively young science. In continue, it is discussed about its importance. The aim of any fisheries survey is to estimate the parameters (such as abundance, catch rate and etc.) with the maximum accuracy and minimum variance, but also at the lowest possible cost. The knowledge of the way in which different sampling stages affect the results variability let us know these more sensible stages in order to improve their precision and their effect on the total variability. The only way to improve the quality of survey results in this situation is increasing the number of hauls in the survey, but this is the most expensive of the three sampling stages. Apart from the cost of sampling, the time for survey is also limited by the schedule of the vessel. There are a number of analytical strategies for producing estimates of parameters with confidence intervals from samples that have an unknown probability distribution. Generally, bootstrap is a method for generating estimates of bias, standard errors and confidence intervals around parameter estimates that was utilized in this paper. Bootstrap method have been applied to fishery surveys in various studies. For example, Magnnusson et al. introduced the Bootstrap, delta and MCMC methods for measuring uncertainty in fisheries stock assessment. Also, Elvarsson et al. utilized bootstrap method for estimating bias and variance in statistical fisheries modelling.

Also we used randomization test for comparing the mean catch rate (kg h⁻¹) of the selected species in different depth strata. When used to test hypotheses, standard parametric statistics such as analysis of variance (ANOVA) require the samples and data involved to adhere to at least one restrictive assumption. If data fail to meet the conditions laid down in such assumptions, any conclusions drawn from the analyses can be suspect. Randomization methods can also be used to test hypotheses but require fewer assumptions. Given this extra flexibility, it is surprising that there is not a greater awareness of randomization test. Here, we cited some researchers that use the randomization tests in their studies. Prager and Hoenig used a randomization t-test to compare recruitment of Chub mackerel (*Scomber japonicas*) in different years with extreme events to recruitment. Also, Haddon used the randomization test to compare mean total length of caught fish between inshore and offshore water.

**Conclusion**

In this research, we attempted to show accuracy of uncertainty methods in fisheries analyses in the region and beyond. Thereafter, the minimum and maximum catch rates of *P. semisulcatus* (with 95% CI) was recorded between 2.7 to 8.8 kg h⁻¹ in Bushehr coastal waters, which this is not significantly different among three depth strata (stratum A: <10 m depth, stratum B: 10-20 m and stratum C: >20 m depth).

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