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Review of Japan's approaches to reduce bycatch of juvenile bigeye tuna by purse seine on FADs in tropical area of the western and central Pacific Ocean

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Abstract

Japanese approaches to mitigate bycatch of juvenile bigeye tuna by purse seine on FAD in the western and central Pacific Ocean in recent years are reviewed. These attempts are collaborative works between Japanese fishery industry, Fishery Research Agency of Japan and Japanese government, which are corresponding to CMM2008-01 Paragraphs 25 and 26 (Juvenile Tuna Catch Mitigation Research). Almost of works intended to reduce bigeye bycatch on FAD by improving fishing methods and equipment. We applied new fishing methods on FADs operation, such as various depths of underwater structures of FAD, multiple FADs in one operation, signals of acoustic or illumination to control movement of tuna forage relative to FAD. Purse seine with large mesh size have been used in the fishing ground supposed that the large mesh to induce escape of small fish. Recently developed broad spectrum sonar was also tested, which intend to identify tuna species and estimate fish size before a fishing operation. Effect for reducing bigeye tuna of these attempts were tested by analyses of fishery statistics, through field examinations using net pen and field researches in the fishing grounds conducted by commercial fishing vessels and research vessels. We also investigated the relationship between bigeye tuna catch and oceanological conditions, and studied on relationship between school type and juvenile tuna catch. The results of these studies are cited in this document for easy to overview.

Introduction

Japanese fishery industry, Fishery Research Agency of Japan and Japanese Fisheries Agency approach to mitigate bycatch of juvenile bigeye tuna by purse seine on FAD in the western and central Pacific Ocean in recent years, which are corresponding to CMM2008-01 Paragraphs 25 and 26 (Juvenile Tuna Catch Mitigation Research). Almost of works intended to reduce bigeye bycatch on FAD by improving fishing methods and equipment. In order to establish the mitigation measure we have held a total of seven domestic meetings with principle members of Japanese fishery industry, fishing gear company, Japan Far Seas Purse Seine Fishing Association, Fishery Research Agency of Japan and Japanese Fisheries Agency. In this meeting results of survey were reported, and future policy and the work plans were discussed. The aim of the document was to review these Japanese approaches and related studies to mitigate bycatch of juvenile bigeye tuna by purse seine on FAD in the western and central Pacific Ocean in recent years.

We applied new fishing methods on FADs operation, such as various depths of underwater structures of FADs, multiple FADs in one operation, signals of acoustic or illumination to control movement of tuna forage relative to FAD. Large mesh purse seines have been used in the fishing ground supposed that the large mesh to induce escape of small fish. Recently developed broadband split-beam system was also tested, which intend to identify tuna species and estimate fish size before a fishing operation. Effect for reducing bigeye tuna of these attempts were tested by analyses of fishery statistics, through field examinations using net pen and field researches in the fishing grounds conducted by commercial fishing vessels and research vessels. We also investigated the relationship between bigeye tuna catch and oceanological conditions, and studied on relationship between school type and bigeye tuna catch. Some of studies are premature as of now, however for easy reference all the results of these efforts are cited in this paper.

Research on FADs

Behavior of small bigeye, yellowfin and skipjack tunas around drifting FADs (Matsumoto *et al*. 2005, 2006, 2007, 2012)

Swimming behavior of bigeye, yellowfin and skipjack tunas associated with drifting FADs was observed using coded transmitters in the equatorial area of central Pacific in 2005 (July and August). There were two successful tracking which consisted of 105 (30 skipjack tuna, 43 yellowfin tuna and 32 bigeye tuna) individuals or about 26 days of monitoring. For several individuals, including skipjack tuna, we succeeded in monitoring for several days. Also, all three species were monitored simultaneously. Some individuals left the FAD temporarily in the daytime or night during the tracking, but the pattern was not regular. It seems that swimming depth of bigeye and yellowfin tunas was similar and related with the depth of upper limit of thermocline, that is, both species mainly stayed in or just under the mixed layer similarly, where water temperature was more than 24℃ in the first tracking and more than 26℃ in the second tracking, although they sometimes dived to the middle or lower part of the thermocline (up to about 150-200m). Swimming depth of skipjack was a little shallower than that of the other two species. Difference of swimming depth by fish size was partly observed, that is, smaller fish distributed at shallower layer than larger fish, but the difference was not always consistent. Swimming depth during night was usually shallower than that during daytime for all species, but it was not clear for several individuals. Based on the difference of swimming depth during night by species, it is suggested that it is possible to reduce the catch of yellowfin and bigeye tuna by purse seine fishery to some extent.

Effect of depths of underwater structures of FAD on bigeye catch (Satoh *et al*. 2007, 2008)

The study of the vertical distribution of the three species around drifting FADs (fish aggregating devices) indicates that the skipjack tuna distribute relatively shallower depth layer (Matsumoto et al. 2006). A typical FAD consists of floating foundation and underwater structures, which is used-up fishing net. Therefore shortening the length of the underwater structure of FADs (depth of FADs) may be effective to reduce the bigeye tuna catch. Relationship of the species composition of purse seine catch and the depth of FADs was investigated by port samplings and by log book, of 17 sets and 65 sets, respectively from May to June 2007. The analysis was a preliminary because of small sample sizes in both data sets. The clear relationship between the presence/absence of bigeye tuna catch and the depth of FADs was not obtained by generalized linear model (port sampling; Chi-Square 0.11, $P = 0.7365$ and log book; Chi-Square 2.20, $P = 0.1376$). It was found that the depth of FADs had no significant effect on the ratio of bigeye tuna catch to total catch per set (port sampling; $F1, 4 = 2.57$, $P = 0.1839$ and log book; $F1, 23 = 0.19$, $P = 0.6711$). The effects of the depth of FADs for the amount of skipjack and yellowfin tuna catch were also investigated and both the catches were not significant with the depth of FADs.

Using multiple FADs in one operation (Kawamoto *et al*. 2012)

A research to mitigate bigeye tuna fishing mortality by using two separate FADs with underwater light stimulus (herein after referred to *Double-FADs*) was done. This purpose of this paper is to verify effects of decreasing bigeye tuna catch of *Double-FADs* as compared with common FADs (herein after referred to *Normal-FADs*). The total number of operation was forty eight (48) including 6-*Double-FADs*, 8-*Normal-FADs* and 34-Free school operations, which were conducted by a commercial vessel "Wakaba-Maru No.3" in November and December 2011 in exclusive economic zone of Papua New Guinea and Solomon Islands by using the assistance fund of the Fisheries Agency of Japan. Based on the onboard sampling data, the size proportion of *Double-FADs* is bigger than that of *Normal- FADs* in all species including skipjack, yellowfin and bigeye if we count number of fish which weight is bigger than 3.0kg on *Normal-FADs* compared with *Double-FADs.* The bycatch rate of bigeye tuna to total number with *Double-FADs* and *Normal-FADs* was 6.1% and 8.9% in number, and 7.2% and 14.2% in weight respectively. The number of bigeye tuna in catch of one (1) metric ton is estimated as 24 in *Double-FADs* and 45 in *Normal-FADs*. Although sample size and quality is not enough to reach conclusion and to apply appropriate statistical test, these results support that *Double-FADs* have some effect on reducing bigeye tuna bycatch as compared with *Normal-FADs*.

Signals of illumination to control movement of tuna forage relative to FAD (Hasegawa *et al.* 2011, Oshima *et al.* 2012)

Three joint research cruises were done during the period from 2009 to 2012 with the intention of developing methods to mitigate by-catch of bigeye in purse seine FADs operation. A fishery research vessel "Shoyo-maru" of Japan Fishery Agency and a tuna seiner "Nippon-maru" chartered by Fisheries Research Agency participated in the research cruises. Light stimuli were applied in attempts to move bigeye schools and let them escape through the mesh or underneath the net. The movements of fish were observed with coded pingers, scanning sonars, a wide-band quantitative echo sounder, and an underwater camera. Introducing new micro coded pingers (Fusion Inc.) in 2011 resulted in longer survival or / and retention of tagged fish. Consequently large data sets of the movement of bigeye and skipjack around FADs with or without light stimuli were obtained.

Purse seine gear configuration, equipment

Broadband split-beam system (Okamoto *et al.* 2020, Imaizumi *et al.* 2011, 2012)

The selective capture of tunas; bigeye tuna (*Thunnus obesus*), skip jack tuna (*Katsuwonus pelamis*) and yellow fin tuna (*Thunnus albacares*) is important for Japanese seine net fisheries. Classification of the species composition by using acoustic information before catching them will significantly contribute for the selective catch. Target strength spectra (TSSP) of each species were measured by a broadband split beam system. Each tuna species was separately kept in a enclosure, which sized 8 x 8 m square and approximately 5 m in depth. This system was able to measure not only TSSP but also a swimming track of individual in 3D. The differences of TSSP among three species were confirmed. For example, the target strength value of bigeye whose tilt angle was 0 degree about 10 dB higher than skip jack tuna one. Swimbladder sizes were measured for each species by soft X-ray because skip jack tuna are physoclist species, and others are physostome species. There were differences of the swimbladder shape between bigeye tuna and yellow fin tuna. The TSSP seemed to be depend on not only body size (fork length), but also swimbladder shape. The TSSP could be useful information to classify among tunas.

Effect of school type, and large mesh size on catch of juvenile tuna (Satoh *et al.* 2012)

Relationship between juvenile tuna catch and school type are investigated. The catch information is collected from log book and market slip (fish unloading data). In recent two years, set with free school of Japanese purse seine has been dominated, that is, the ratio of set number with associated school has been reduced. In same time catches of bigeye tuna, small yellowfin and small skipjack decreased. Generalize linear model analysis indicate that the decrease of these catches are significantly influenced by the decrease of the ratio of set number with associated school. These results suggest that if the ratio of associated school is monitored appropriately, the regulation for the ratio is possible management measures for mitigation measures of juvenile tuna described in CMM 2008-01.

The annual changes of number of cruise by maximum mesh size showed that purse seine with larger mesh size was gradually introduced since 2004 and the proportion of cruise using more than 300 mm mesh was 62.5% in 2011. Some vessels introduced the purse seine with 450 mm mesh size in cooperation with the granted project of Japanese Fisheries Agency. The effect of purse seine mesh size was not found in all species and sizes, when the mesh was divided by 300 mm. The increasing of number of vessel using the large mesh may result from the ingenuity to operate more efficiently for the free school, that is, the net with the large mesh tend to sink faster.

Other approach

Relationship bigeye tuna catch and oceanological conditions (Masujima *et al.* 2009)

Extracting oceanic region of small by-catch rate of bigeye tuna (BYT) to skipjack (SKJ) is a goal of this study. We used 350,045 data of logbook mandatory reported by purse seine fishermen (PS) in the region of 130 ˚ E-180 ˚E and 10 ˚S-10 ˚N between the year of 1967 and 2008. Each data contains positions of PS operation, catch amount by species, school-type and sea-surface temperature. These data show that the SKJ catch is averagely increasing annually, and the fishing grounds averaged meridionally are moving horizontally in sync with the horizontal movement of region of 29˚C sea surface temperature. BYT by-catch rate, defined as [BYT catch] / ([SKJ catch] + [BYT catch]) for each PS operation, was found to be largely increased after the year of 1997 when the FADs was introduced. On the other side, geographical distribution of the BYT by-catch rate shows that the low area (below 10%) is often found in west of 150 ˚ E and the high latitudes area in the east of 150 ˚ E, which suggests that PS operation at this area can lead to reduce the BYT by-catch rate. Comparing average vertical profile of seawater between the low and high (above 10%) by-catch area using 4D-VAR data (Japan Agency for Marine-Earth Science and Technology), temperature and salinity above 200m depth in the low by-catch area are respectively 1 ˚C higher and 0.15 psu lower than that of the high by-catch area.

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