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Technological developments of the fishing devices in the Japanese pole-and-line vessel identified in past surveys

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Executive summary
SC19 has pointed out that next stock assessment of skipjack tuna should take into account improvements in catch efficiency resulting from technological developments in fishing devices as technological (or effort) creep. This document aims to identify the technological creep of the Japanese pole-and-line fishing devices based on the results of valuable interviews and questionnaires conducted by FRA. A comparison of the chronology of technological developments obtained from the interviews with the records of fishing gear (sonar and bird radar) presented in Matsubara et al. (2022) revealed that sonar equipment on fishing vessels shifted from monochrome to color monitors in the 1980s, and that the rate of installation tended to increase rapidly during the same period. A similar trend was also observed for bird radar, with its power efficiency doubling from the late 1980s to the 1990s. In addition, the results of a questionnaire survey of off shore pole-fishing vessels revealed that important equipment such as sonar and bird radar were installed in a coherent period of time, although the introduction of equipment was slightly slower than for larger vessels. These supports the argument for specific technological advancements, and the results suggest a rapid change in fishing efficiency due to technological development. Therefore, technological creep is an issue that cannot be ignored in assessing long-term trends of the skipjack tuna stock, and more detailed surveys for quantitative assessment in changes in catch efficiency will be needed in the future.

1. Introduction

Currently, skipjack stock assessments have been conducted primarily using CPUE indices based on data from pole-and-line fisheries. In those assessments, catchability is often assumed to be time-invariant for its simplicity for modelling, and temporal changes are not considered. However, various literatures have shown that regardless of the species or fishing method, catchability is clearly changing with the development of fishing vessel equipment.

Temporal changes in catchability due to technological developments in fishing gear such as sonar and bird radar are referred to as technological creep (essentially synonymous with effort creep, the only difference being whether one focuses on catchability or effort). Various research cases have pointed out that long-term stock assessment that ignores the technological creep leads to overestimation of stock abundance (Thurstan et al. 2010; Eigaard et al. 2014; Rousseau et al. 2019). Technological developments in Japanese pole-and-line (JPPL) fishing vessels for skipjack has been shown by Matsubara et al. 2022, and the issue of technological creep can lead to significant bias in the assessment of long-term trends. In fact, an excessively stable state of skipjack stock dynamics has been reported, and this was discussed considerably at the 2022 preliminary assessment workshop, suggesting that a detailed analysis is needed (Hamer 2022). Interviews and surveys that incorporate field conditions into quantitative data are known to be effective in resolving these technical creep issues (Marchal et al. 2007; Marriott et al. 2011).

This document aims to further clarify the technological evolution of JPPL fishing gear as presented in Matsubara et al. 2022, based on the results of valuable past interviews and questionnaires conducted by Fisheries Research Agency (FRA) for proper skipjack stock assessment. We developed a chronology of technological developments from the results of the interviews and compared them to the records of fishing gear (sonar, bird radar) presented by Matsubara et al. (2022) to determine if there is any overlap between technological developments and timing in the installation of equipment on fishing vessels. We also examined the timing and frequency of equipment installation on fishing vessels obtained from the results of a questionnaire survey of off shore JPPL fishing vessels. Finally, future issues and plans are summarized in order to address the issue of technological creep and to achieve an appropriate skipjack stock assessment.

2. Materials and Methods

2.1 Technical creep in the Japanese pole-and-line fishery

The JPPL operational process is outlined below (see Matsubara et al. 2022 for details). First, live bait (sardines or anchovies) is loaded onto the vessel after departure. The fishermen then determine the approximate fishing grounds by referring to various environmental data (sea surface temperature, ocean currents, etc.) from satellite data and catch information from radio receivers from other vessels. To find more detailed fishing points, fishermen use bird radar, sonar, and fish finder to determine more specific fishing locations. The bait tanks, satellite data, bird radar, sonar, and other equipment discussed here have all improved in performance over time. These clearly have an impact on catchability, but are not reported in the data. Interviews with manufacturers and questionnaire surveys of fishermen are essential to solidify the argument for technological creep.

2.2 interview data

We have compiled a chronology of the development of equipment for bird radar and sonar based on the transcripts of interviews conducted by FRA in 2011 with several distributors. Here, we decided to summarize bird radar and sonar because historical information on other equipment, such as satellite imagery data systems and fish finders, was limited to fragments. The subdivisions covered are: bird radar, (full-surrounding) low-frequency sonar (searching for distant fish schools), (full-surrounding) high-frequency sonar (high-resolution searching for nearby fish schools), and half-surrounding sonar (narrower search range but faster search time than the full-surrounding type). In this document, we have prepared a table of the time of change from monochrome to color sonar (including the output (kw) for bird radar), which is a particularly significant development, in a span of five years. This five-year span is to reduce uncertainties in the data as well as to summarize multiple pieces of information.

2.3 Questionnaire survey data

Based on data from a questionnaire survey of skippers of off shore JPPL vessels conducted by FRA in 2011 (N=45), a frequency distribution of the year each piece of equipment was installed was developed. The equipment covered here are bird radar, vessel radar, low-frequency sonar, high-frequency sonar, semi-circular sonar, satellite imagery weather receiver, fishing ground forecasting system, bait tank, and automatic pole-fishing machine. A table was also prepared for the response rate for each question item. The response rates should be helpful in determining how many people to target and what types of questions to ask in future surveys.

3. Results

A history of the development of operational equipment in the JPPL skipjack fishery was developed from records of past interviews (**Table 1**). Overall, it was found that sonar was developed earlier than bird radar, with sonar developed in the earlier 1980s and bird radar developed in the 1990s.

Using the records from the questionnaire survey, a frequency distribution of the year of installation of each type of equipment on off shore JPPL vessels was created, and it was found that the equipment was installed collectively between 2000 and 2005, although there was some variation (**Figure1**). The bird radar and the low-frequency sonar, respectively, were of the single mountain type between 1990 and 2005, and between 2000 and 2005, respectively. The response rates for each item were nearly twice as high, with a maximum of 37.8% (bird radar) for those where the year was specifically known and 73.3% (bird radar and high-frequency sonar) for those where the age was not known but it was known that the radar was installed (**Table 2**). The response rates were higher for bird radar, vessel radar, and low-frequency sonar than for the other items.

4. Discussion

A comparison of the chronology of technological developments obtained from the interviews with the records of fishing gear (sonar and bird radar) presented in Matsubara et al. (2022) revealed that sonar equipment on fishing vessels shifted from monochrome to color monitors in the 1980s, and that the rate of installation tended to increase rapidly during the same period. A similar trend was also observed for bird radar with its power improvement that can enlarge searching range from the late 1980s to the 1990s. In addition, the results of a questionnaire survey of off shore JPPL vessels revealed that important equipment such as sonar and bird radar were installed in a coherent period of time, although the introduction of equipment was slightly slower than for larger vessels (Matsubara et al. 2022). These supports the argument for specific technological advancements, and the results suggest a rapid change in fishing efficiency due to technological development. Therefore, technological creep is an issue that cannot be ignored in assessing long-term trends of the skipjack tuna stock, and more detailed surveys for quantitative assessment in changes in catch efficiency will be needed in the future.

Questionnaire surveys could reveal equipment and phenomena that skippers, fishing masters and fishermen perceive as important for improving fishing efficiency (Marchal et al. 2007; Marriott et al. 2011).

For example, equipment such as vessel radar, frequency of receipt of weather forecasts, and ability to transmit them (with recent advances through communication tools such as “LINE”) are perceived to be important for locating flocks of birds and setting up fishing grounds. Questions regarding the extent to which these technological advances have improved catchability were not included in previous surveys and will need to be investigated in the future for proper stock assessment.

Care should be taken in crafting questions to increase the response rate when the next survey is conducted. The survey results in this document indicate a 73.3% response rate for bird radar installation (even if the year is unknown), which is an underestimate and somewhat inaccurate since most fishing vessels should have been equipped with bird radar as of 2011. It is possible that the fishermen did not answer the question because of some inconvenience or disadvantage to them. Questionnaire surveys are easier to sample than interviews, but to take full benefit of this advantage, the question contents need to be scrutinized. In the survey, it would be necessary to make the questions psychologically easy to answer and to communicate in advance the significance of accurately answering the survey (e.g., necessary for correct resource evaluation).

5. Future work plan

The results of the interviews and questionnaire survey presented in this document support the issue of technological creep from the history of technological developments, and these are the first step toward an appropriate assessment of skipjack stock, based primarily on pole-and-line fishery data. In the future, we plan to combine the pole-and-line fishery data with the data from the questionnaire survey to evaluate long-term stock trends that solve the problem of technological creep (**Figure 2**). First, we will show whether it is possible to estimate q_t (time-varying catchability parameters) using a statistical modeling approach with virtual data that mimic catch records and survey data in a simulation. Here, we show that forming a prior distribution of parameter q_t based on the results of the questionnaire survey increases the accuracy of the estimation. Next, we will analyze the actual data using the actual catch records and the data obtained from the questionnaire survey and conduct a long-term stock trend assessment (scheduled for 2025). 2023-2024 work plan is to conduct the questionnaire survey, develop statistical modeling methods, and conduct simulations.

6. References

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7. Tables and Figures

Table 1. History of the Development of Operational Equipment in the Japanese pole-and-line Fishing Fishery. Monochrome and color represent the display format of the image. The kw of bird radar is the output, and an increase in output indicates an increase in search area.

	1970~	1975~	1980~	1985~	1990~
Bird_radar				Monochrome, 30kw	Color, 60kw
Soner_low_freq	Monochrome	Color			
Soner_high_freq			Color		
Semi_type_sonar		Monochrome	Color		

Table 2. Response rates for each question in the survey (N=45). The response rates are shown for the cases where information on the specific time period in which the device was installed was included in the response and for the cases where it was not included in the response.

Question items	Response rate	Response rate (excluding unknown year)
Bird_radar	71.1% (n=32)	37.8% (n=17)
Vessel_radar	73.3% (n=33)	35.6% (n=16)
Soner_low_freq	26.7% (n=12)	13.3% (n=6)
Soner_high_freq	73.3% (n=33)	33.3% (n=15)
Semi_type_sonar	0% (n=0)	0% (n=0)
Satellite_climate_image_receivers	24.4% (n=11)	17.8% (n=8)
Fishrey_pred_system	42.2% (n=19)	24.4% (n=11)
Bait_tank	2.2% (n=1)	2.2% (n=1)
Auto_pole-and-line_machine	11.1% (n=5)	8.9% (n=4)

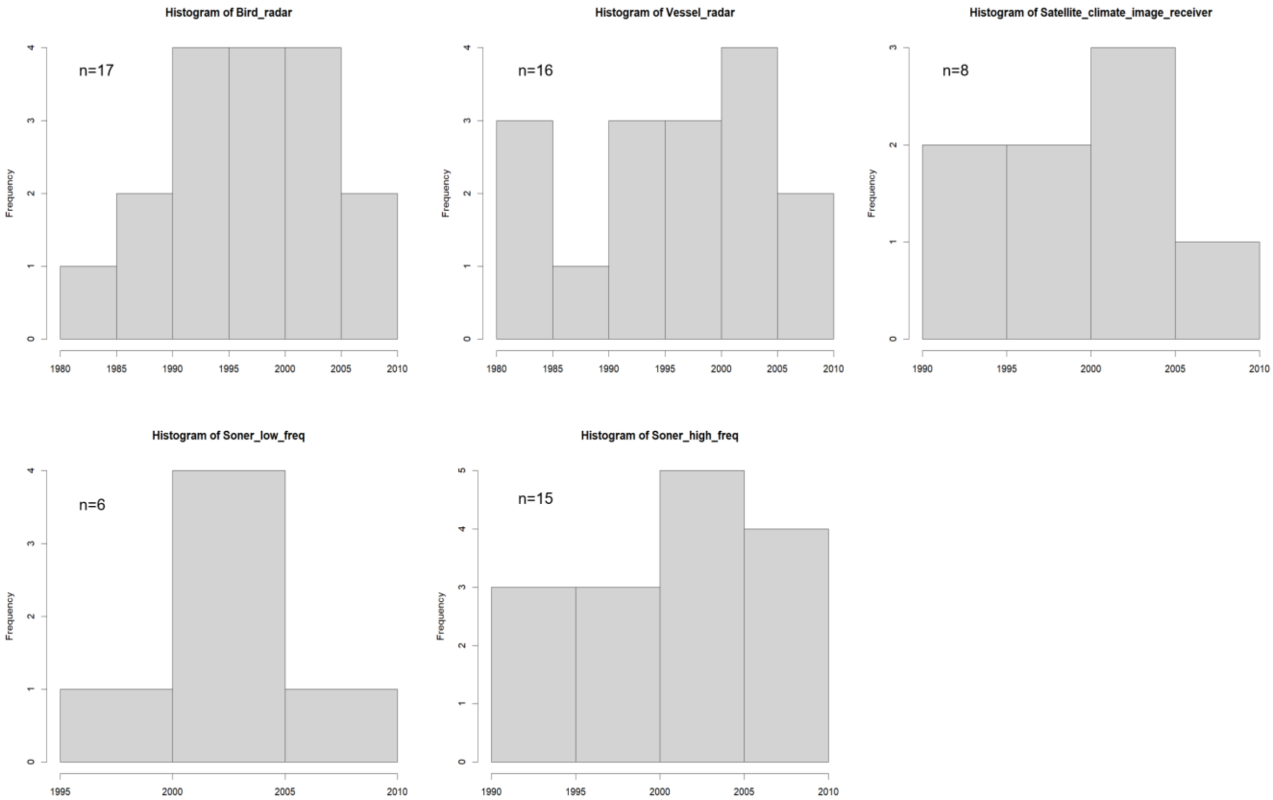

Figure 1. Frequency distribution for each device (bird radar, vessel radar, satellite imagery weather receiver, low-frequency sonar, and high-frequency sonar). For the other items, there were no responses for the semi-circumferential sonar, all of the fishery forecasting systems were reported to have been installed in 2005 (n=11), one bait tank was installed in 2005, and the automatic pole-fishing machine was installed in two cases each between 1990-1995 and 2005-2010.

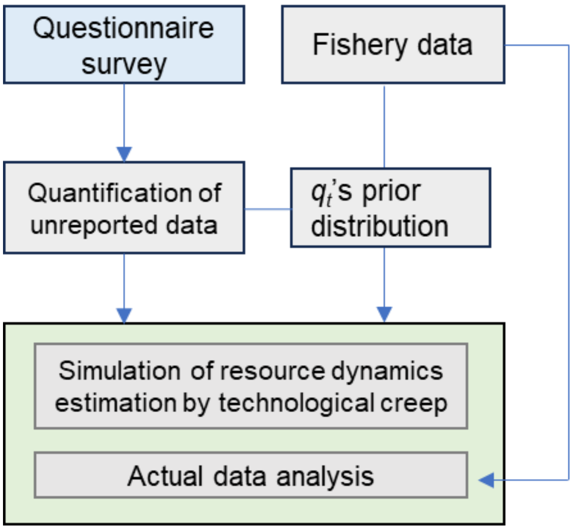

Figure 2. Outline of future research schemes. Here, q_t denotes a time-varying catchability parameter in $C_t = q_t E_t N_t$.