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Potential application of an underwater towing camera system for a trolling survey of southern bluefin tuna recruitment

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Abstract : An underwater video camera system was developed, which was capable of being towed at speeds as high as 8 knots during trolling. Using this system, fish behavior during trolling for southern bluefin tuna (SBT), *Thunnus maccoyii*, was observed. Trolling was conducted as a pre-recruitment monitoring survey of SBT off the southern coast of Western Australia during January and February, 2010. Of the eight trolling lines used, one was equipped with a depressor and attached to the underwater video camera system. A total of 714,071 frames of video images (approximately 6.7 hours) were recorded using the underwater camera, and images of SBT were detected in 4,465 of them. Video images of SBT were classified based on 3 types of fish behavior directed towards trolling gear; "No response", "Following the gear", and "Approaching the lure". When SBT hooking was unsuccessful "No response" behavior was frequently observed, and when SBT hooking was successful "Approaching the lure" behavior was mainly observed. These results clearly demonstrated that success of trolling was affected by behavior of fish towards trolling gear. Underwater camera allowed for detection of SBT even when catches were unsuccessful, and this is a highly advantageous feature as the alternative tool of SBT school detection for pre-recruitment monitoring surveys.

Key words : catch efficiency, fish behavior, pre-recruitment survey, southern bluefin tuna, trolling, underwater towing camera

Introduction

Pre-recruitment surveys provide annual indices of year-class strength and improve understanding of the recruitment mechanisms of commercially important fish stock (e.g. van der Linden and Huggett, 2003). Long-term monitoring is essential for the comparison of recruitment success between years, which aids in the understanding of natural and anthropogenic effects on fish stock reproduction (Walters and Pearse, 1996; Cowx *et al.,* 2009). Being able to assess recruitment status and consider adequate stock management strategies is also helpful in the management of commercial fish stocks (Walters and Pearse, 1996). A number of pre-recruitment monitoring programs employing a variety of approaches (e.g. catch/acoustic monitoring, sighting, and spotting) are used to examine commercial fish stocks all over the world (e.g. Hutchins and Pearce, 1994; Wespestad *et al.,* 2000; Swartzman *et al.,*2005; Itoh, 2007; Willis, 2008). For southern bluefin tuna (SBT), *Thunnus maccoyii,* the Fisheries Research Agency (FRA) of Japan have carried out pre-recruitment monitoring surveys for age-1 fish along the southern coast of Western Australia since 1988. Trolling/pole-and-line catch operations were used as monitoring methods for the first five years of surveys; however, surveys employing acoustic monitoring with sonar and echo sounders have been used since the mid-1990s. In 2006, line-transect trolling surveys were adopted as the survey method of choice (Itoh *et al.* 2009). In the most recent trolling survey, it was assumed that trolling catch events of SBT represented the

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encounters with their schools, and the number of schools detected per trolling distance was provided to the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) as a recruitment index for stock assessment of SBT.

Advantages of trolling surveys include the fact that they are both simple and cost-effective; however, trolling surveys also have disadvantages associated with the sampling gear used. Catch efficiency during trolling surveys has not been determined, and catching success is generally impacted by the effectiveness of fishing gear (Arreguín-Sánchez, 1996); therefore, an inherent uncertainty regarding SBT school detection capability exists in surveys that utilize trolling. It has been pointed out that fish behavior during the catching process is one of the major factors that affect the catching success of fishing (Løkkeborg *et al.,* 1989). One way to observe fish behavior towards fishing gear during the catching process is to utilize underwater video recordings (Graham *et al.,* 2004). A number of video experiments have been conducted regarding the effectiveness, selectivity, and fishing processes associated with trawl net, gillnet, longline, and trolling fishing methods (Løkkeborg *et al.,* 1989; Albert *et al.,* 2003; Grant *et al.,* 2004; Akiyama *et al.,* 1995; Akiyama *et al.,* 2011). It was expected that video recording would serve as a useful means of improving understanding of catch efficiency in SBT trolling surveys.

The purpose of the present study was to describe characteristics and catch processes associated with the trolling gear currently used to survey SBT populations. In order to observe catching processes and behavior of SBT directly, underwater video images were taken during trolling surveys. Based on the video images and trolling catch data obtained, the effect of fish behavior on trolling catch efficiency was analyzed. The potential for underwater cameras as an alternative to trolling in the detection of SBT schools was also discussed.

Methods

SBT trolling surveys have been conducted by F/V “St. Gerard M” (18m, 28t) off the southern coast of Western Australia (34-35.5°S, 117.5-122°W) every January and February since 2006 (Fig. 1). Underwater camera experiments were conducted during trolling surveys undertaken in the daytime on 22-24, and 26 January 2010. Trolling survey was usually conducted from 5:00 AM to 4:00 PM, and underwater camera was employed for 1-2.5 hours per day during the trolling survey. Total duration of underwater camera experiments was about 7 hours. Eight fishing lines were employed in typical trolling surveys, two of which were equipped with a trolling depressor (Yo-zuri diving board K-type #11, DUEL Co., Inc.) in order to maintain fishing lures and hooks at a depth of approximately 5 m. Trolling speed was around 7-8 knots. During underwater video experiments, a compact digital camera (Optio W60 or 80, Pentax Ricoh Imaging Co., Ltd.) situated within a waterproof housing was attached to one of the fishing lines that was equipped with a depressor. The camera was arranged so as to record rearward-facing video images (30 frames per second) in order to observe SBT behavior towards the trolling gear behind the underwater camera. The camera lens was oriented downward and backward with the sea surface within its field of view. 35 mm equivalent focal length of the camera was set to 28 mm. Underwater angle of view was 44 degrees (vertical) and 29 degrees (horizontal). The hook was removed from the line that the camera apparatus was attached to (Fig. 2). Camera depth was recorded using an ultra-miniature depth recorder (MDS-MkV/D, JFE Advantech Co., Ltd.).

Video images taken were examined on laboratory computer monitors. In order to determine the influence of fish behavior on trolling catch efficiency, SBT individuals which were identified within video images was compared with/without trolling catch events that occurred around the same time periods (within 5 minutes of SBT observation on camera). In this analysis, if SBT was hooked by any of the trolling lines except for the line with underwater camera, it was defined as the “trolling catch events”. For the purposes of this analysis, the behaviors of each SBT individual sighted into video images was classified using the following fish behaviors towards trolling gear;

1) SBT showed no response to trolling gear,
2) SBT followed trolling gear (or boat),

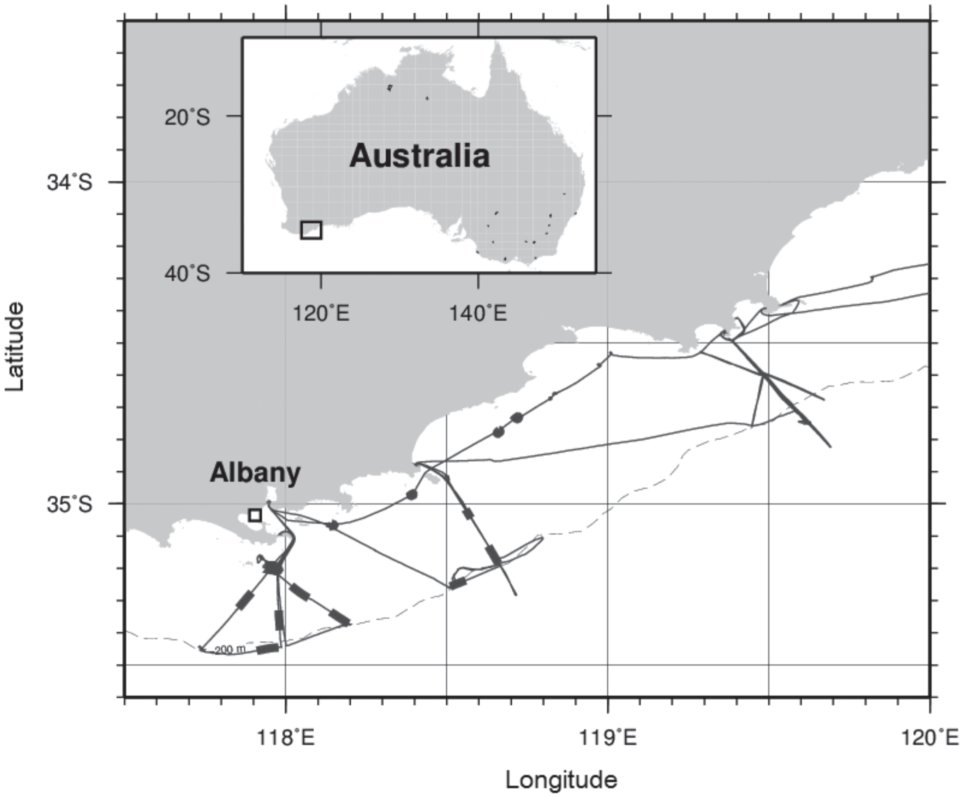

Fig. 1. Location of the SBT pre-recruitment trolling survey conducted in 2010. Thick line indicates location of the underwater camera experiment. Thin line indicates cruise track of the survey. Dashed line indicates the 200 m isobath.

3) SBT approached fishing lure.

Every SBT individual which came into the video frame was treated as different individual, even if there were a possibility that same fish came into view again after going out of the video frame once.

Furthermore, trolling catch events were grouped based on presence or absence of SBT in video images. SBT hooked by any of the trolling gears or SBT sighted by the underwater camera were defined as SBT detection, and each detection capability was compared by dividing experimental periods into 10 minute blocks. Usually, each trolling catch event did not continue more than 5 minute, and SBT individuals in video images tended to go out of the frame immediately (less than a few seconds). Therefore 10 minute was assumed as a reasonable time block length to analyze the relationships of SBT detection between trolling gear and underwater camera.

Statistical analysis was conducted using R 2.10.1 (R Development Core Team, 2009).

Results

During underwater camera experiments, camera towing depth remained stable at around 6-7 m. After eliminating some blurred images, 714,071 frames of video images (about 6.7 hours in total) were used for the analysis. SBT images were detected in 0.6% of them (4,465 frames). 2,650 frames of SBT images showed SBT that approached the fishing lure (51 individuals). The other two behaviors, SBT that followed trolling gear or demonstrated no response to trolling gear, were observed in 410 frames (3 individuals) and 1,405 frames (70 individuals), respectively. The presence or absence of SBT hooking events was associated with observed behaviors of SBT individuals (Pearson's Chi-squared test; Chi-squared=45.8558, df=2, $p<0.001$) (Fig. 3). Fish that exhibited no response to trolling gear behavior were frequently observed (76% of observed individuals) when hooking events did not occur. On the other hand fish that exhibited approaching the

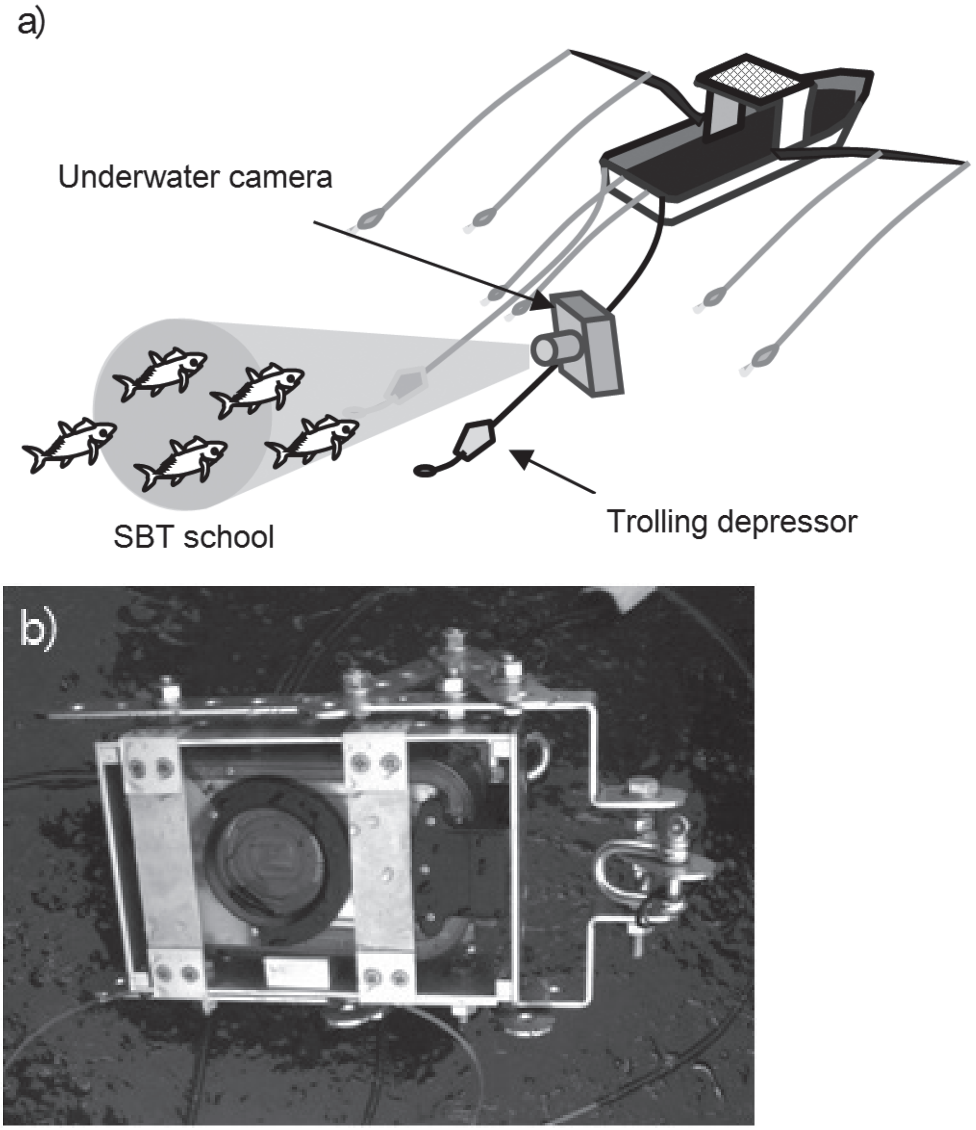

Fig. 2. Underwater camera and trolling gear configuration; a) Experimental gear arrangement for underwater video recording of fish behavior during trolling operations. Eight fishing lines were used, and an underwater camera was attached to one of them. The fishing hook that had been attached to this line was removed during video experiments. b) Underwater camera: a compact digital camera situated within a waterproof housing.

fishing lure behavior were frequently observed (86% of observed individuals) when hooking did occur.

When detection of SBT schools using video imaging and hooking events at 10 minute intervals was compared, the experimental durations were divided into 41 time blocks in total, and it was determined that trolling gear was only capable of detecting around half (55%) of the SBT schools detected by the underwater camera (Fig. 4); however, a few cases (10%) in which the underwater camera could not detect SBT schools that had been detected by trolling gear did exist.

Discussion

Trolling is an effective method of locating fish schools; however, based on relative behaviors of target species and fishing gear used, trolling is classified as a passive fishing method (Bjordal, 2009). Catching success with passive fishing gear generally

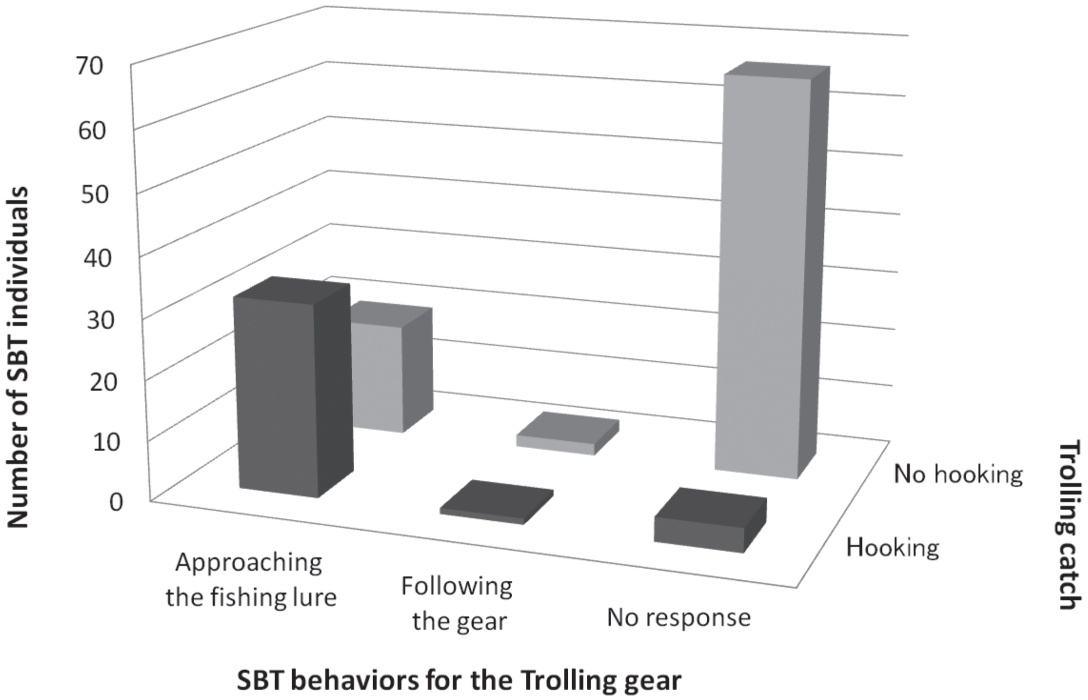

Fig. 3. Trolling catch events and SBT behaviors observed during associated time periods.

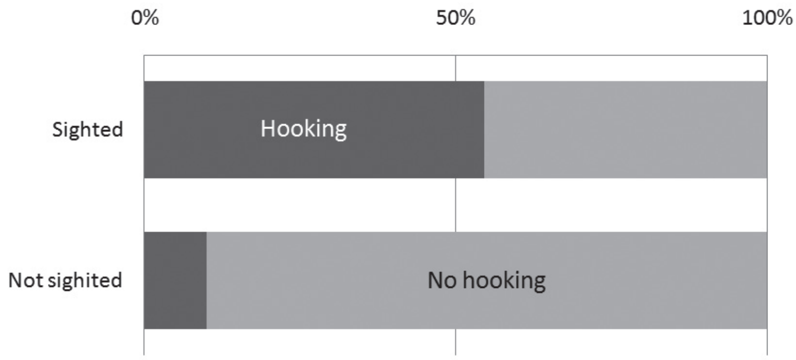

Fig. 4. Trolling hooking rate associated with SBT schools sighted/ not sighted by the underwater camera. Presence/absence of underwater sighting and troll hooking was summarized by 10 minutes time blocks. Number of time blocks for "Sighted" data and "Not-sighted" data were 11 and 30, respectively.

depends on movement of fish toward that gear, a characteristic that was clearly observed in the present study. The relationship between trolling catches and SBT behavior suggested that trolling catch efficiency was affected by fish behavior towards trolling gear. When SBT reacted to trolling gear by biting into lures but hooking did not occur, schools were not detected by trolling. This resulted in an underestimation of SBT schools during the trolling survey undertaken in the present study; however, some SBT schools that were passed over without capture were detected by the underwater camera.

Fish behavior towards fishing gear can be affected by environmental variables (e.g. temperature, light, current, prey abundance, etc.), thus accommodation and standardization of catch efficiency and fishing methods should be considered when using a catch-based index for stock assessment (Stoner, 2004). Current knowledge regarding environmental influences on trolling catch efficiencies remains inadequate. If any spatial-temporal variability exists in the environmental influences affecting trolling catches, adjustment of survey design and accommodation of survey results in order to obtain more reliable recruitment indices would be required. Actually, it was suggested that the distribution and migration pattern of juvenile SBT off the southern coast of Western Australia had interannual fluctuation (Fujioka *et al.,* 2010). The mechanisms of this fluctuation remain to be fully elucidated, but prey distribution and dynamics might be a key factor (Itoh *et al.,* 2011) that links oceanographic condition and trolling catch success. These environmental influences for fish behavior related to trolling catch should be considered in order to improve the SBT pre-recruitment monitoring survey, although fish behavior is one of the difficult factors to monitor through routine survey activity. Underwater camera system provides an option to detect the fish behavior which is independent from the catching success of fishing gear, and is a useful tool to improve our understanding about catching process and its influence on the monitoring index. This solution may be applied to other fish species which dependent on the fishing survey as well. Continuous monitoring during surveys and more comprehensive data regarding fish behavior are required in order to develop more accurate recruitment indices for stock assessment and habitat modeling. The needs could be fulfilled by the underwater camera system described in the present study.

The underwater camera examined in the present study was capable of detecting fish even if they weren't hooked, something that was not possible using traditional trolling methods alone. Observation using an underwater camera did not require fish to be caught, and was therefore determined to be a less damaging monitoring method for SBT. Due to their non-destructive nature, underwater cameras could prove valuable as a means of surveying vulnerable species or assessing protected marine areas (Assis *et al.,* 2007). Furthermore, observation without catching is also a more cost-effective means of surveying marine populations due the associated laborsaving and time saving characteristics. Results of the present study showed that underwater cameras possessed superior detection capability for SBT schools when compared to trolling gear. The underwater camera system examined possessed a simple structure, was easy to maintain, and was capable of being towed at fast speeds (7-8 knots). These results suggested that underwater cameras could potentially serve as an alternative to the trolling gear currently used to monitor recruitment levels of SBT; however, future studies should control for any possible attractive effects of trolling gear on SBT by examining performance of underwater cameras when used independently.

Room for improvement in the underwater camera system examined still exists (e.g. angle of view, breadth and distance of vision, image stability, species identification, etc.). In fact, the underwater camera did not detect a few SBT schools that were detected by trolling gear, a short coming that could have been the result of a limited angle of view. Further trials using the underwater camera system described in the present study are required in order to resolve these issues and concurrently improve our understanding of the characteristics of SBT behavior associated with trolling. Application of underwater camera systems, as well as their continued improvement, will inevitably increase the quality of recruitment indices obtained from SBT pre-recruitment monitoring.

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References

Akiyama S., Yasuda K., Arimoto T., and Tawara Y., 1995: Underwater observation of fish behavior to trolling line. Nippon Suisan Gakkaishi, **61(5)**, 713–716.

Akiyama S., Ozawa K., and Shiode D., 2011: Underwater observation of fish behavior to artificial bait of trolling line by towed video camera. Fish Engineering, **48**(**1**), 1–5.

Albert O. T., Harbitz A., and Høines Å. S., 2003: Greenland halibut observed by video in front of survey trawl: behavior, escapement, and spatial pattern. Journal of Sea Research, **50**, 117–127.

Arreguín-Sánchez F., 1996: Catchability: a key parameter for fish stock assessment. Reviews in Fish Biology and Fisheries, **6**, 221–242.

Assis J., Narváez K., and Haroun R., 2007: Underwater towed video: a useful tool to rapidly assess elasmobranch populations in large marine protected area. Journal of Coastal Conservation, **11**(**3**), 153–157.

Bjordal A., 2009: Regulation of fishing gears and methods. In: Cochrane, K. L. and Garcia, S. M. (Eds.). A fishery manager's guidebook, Second edition. pp.167–195.

Cowx I. G., Harvey J. P., Noble R. A., and Nunn A. D., 2009: Establishing survey and monitoring protocols for the assessment of conservation status of fish populations in river Special Areas of Conservation in the UK. Aquatic Conservation: Marine and Freshwater Ecosystems, **19**, 96–103.

Fujioka K., Kawabe R., Hobday A. J., Takao Y., Miyashita K., Sakai O., and Itoh T. 2010: Spatial and temporal variation in the distribution of juvenile southern bluefin tuna *Thunnus maccoyii*: implication for precise estimation of recruitment abundance index. Fisheries Science, **76**, 403–410.

Graham N., Jones E. G., and Reid D. G., 2004: Review of technological advances for the study of fish behavior in relation to demersal fishing trawls. ICES Journal of Marine Science, **61**(**7**), 1036–1043.

Grant G. C., Radomski P., and Anderson C. S., 2004: Using underwater video to directly estimate gear selectivity: the retention probability for walleye (*Sander vitreus*) in gill nets. Canadian Journal of Fisheries and Aquatic Sciences, **61**, 168–174.

Hutchins J. B. and Pearce A. F., 1994: Influence of the Leeuwin current on recruitment of tropical reef fishes at Rottnest Island, Western Australia. Bulletin of Marine Science, **54**(**1**), 245–255.

Itoh T., 2007: Introduction of sonar survey for southern bluefin tuna in Australia. In: New technologies in Fisheries acoustics. Resource survey using scientific sonar. (ed. by Iida K., Furusawa M., and Inada H.), pp. 86–95.

Itoh T., Kurota H., and Takahashi N., 2009: Review of the CCSBT scientific program between 2001 and 2005. CCSBT-ESC/0709/41, pp.12.

Itoh T., Kemps H., and Totterdell T., 2011: Diet of young southern bluefin than tuna Thuumus maccoyii in the south western coastal waters of Australia in summer. Fisheries Science, **77**, 337–344.

Løkkeborg S., Bjordal Å., and Fernö A., 1989: Responses of Cod (*Gadus morhua*) and Haddock (*Melanogrammus aeglefinus*) to baited hooks in the natural environment. Canadian Journal of Fisheries and Aquatic Sciences, **46**, 1478–1483.

R Development Core Team, 2009: R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Stoner A. W., 2004: Effects of environmental variables on fish feeding ecology: implications for the performance of baited fishing gear and stock assessment. Journal of Fish Biology, **65**, 1445–1471.

Swartzman G., Winter A., Coyle K., Brodeur R., Buckley T., Ciannelli L., Hunt G., Ianelli J., and Macklin A., 2005: Relationship of age-0 pollock abundance and distribution around the Pribilof Islands, to other shelf regions of eastern Bering Sea. Fisheries Research, **74**, 273–287.

van der Lingen C. D. and Huggett J. A., 2003: The role of ichthyoplankton surveys in recruitment research and management of South African anchovy and sardine. In: The Big Fish Bang. Proceedings of the 26th Annual Larval Fish Conference. (ed. by Browman H.I. and Skiftesvik A. B.), pp. 303–343.

Walters C. and Pearse P. H., 1996: Stock information requirements for quota management systems in commercial fisheries. Reviews in Fish Biology and Fisheries, **6**, 21–42.

Wespestad V. G., Fritz L. W., Ingraham W. J., and Megrey B. A., 2000: On relationships between cannibalism, climate variability, physical transport, and recruitment success of Bering Sea walleye Pollock (*Theragra chalcogramma*). ICES Journal of Marine Science, **57**, 272–278.

Willis J., 2008: Simulation model of universal law of school size distribution applied to southern bluefin tuna (*Thunnus maccoyii*) in the Great Australian Bight. Ecological Modelling, **213**, 33–44.