Measurement of activity for sit-and-wait predator, red-spotted grouper, using acoustic acceleration transmitter

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Abstract
Activity of sit-and-wait predator, red-spotted groupers (Epinephelus akaara), was measured using acoustic acceleration transmitters, AccelTag (Thelma Biotel, Trondheim, Norway). Nine red-spotted groupers tagged with the transmitters were released into a fish tank. The transmitter signal intervals derived from acceleration measured were recorded on acoustic receiver for 1 hour for each individual. At the same time, the fish behaviors were recorded using video cameras. The tail beat frequency of the tagged fish was counted as indicator of fish activity. We compared transmitter signal intervals and tail beat frequency. Our results showed that signal intervals distinguished whether red-spotted groupers moved their tail fin or not, suggesting that acoustic acceleration transmitter could detect the activity of red-spotted groupers. Acoustic telemetry with acceleration transmitter will be useful to apply to other sit-and-wait type predators to understand their movement patterns and activity rhythms.

Keywords: Red-spotted grouper, acoustic telemetry, activity measurement, tail beat, tank experiment

1. Introduction
It is necessary to understand behavior and ecology of the target species for its fishery resource management (Masuda & Tsukamoto, 1998). One of research methods for fish behavior and ecology under natural conditions is acoustic telemetry with transmitters and receivers (Cooke et al., 2004; Yokota et al., 2007; Mitamura et al., 2009; 2012). The acoustic telemetry is a powerful tool to monitor when and where the target fish go for a long period, several months to more than one year. Previous telemetry studies demonstrated that the black rockfish (Sebastes cheni) showed a strong homing behavior to its original habitat after displacement and diel movement within a small home range (Mitamura et al., 2009; 2012), and that the wild and hatchery-reared red tilefish (Branchiostegus japonicus) burrowed mud sea bottom for its shelter and showed diel behavior with its shelter (Yokota et al., 2007). Recently, a new acoustic transmitter equipped with acceleration sensor has been developed. This acoustic acceleration transmitter provides “activity” or “behavior” of the target fish. Payne et al. (2012) showed using by acceleration transmitters that hard rain changed the diel activity rhythm from diurnal to nocturnal patterns for yellow-fin bream (Acanthopagrus australis). Wilson et al. (2013) demonstrated that activity derived from the acceleration transmitter is related to swimming speed of sockeye salmon (Oncorhynchus nerka) and provided insights to its coastal and in-river migration (Wilson et al., 2013; 2014). The acceleration transmitters were also used to detect a specific behavior of a target fish, such as burrowing behavior of toadfish (Halobatrachus didactylus) (Almeida et al., 2013). In these ways, acceleration transmitters provided activity or behavior of fish. Although a specific behavior was detected by this acceleration transmitter, it is possible to measure more general behavior of fish such as sit-and-wait predator which is common in many fish species.

Sit-and-wait predator fish basically remain still until they could detect food items as they approach and only perform short burst to catch them or to exhibit aggressive behavior (Katano, 1995; Metcalfe et al., 1997). In Japan, the red-spotted grouper (Epinephelus akaara) is one of sit-and-wait predator and is distributed in coastal shallow areas through subtropical and temperate region. This species is a commercially important serranid fish and their artificial seedlings have been released into the sea for stock enhancement (Kayano, 2001). Adult red-spotted groupers may not show movements during the daytime but active movements for foraging during the nighttime and the crepuscular time (Itani et al., 2005; Masuda et al., 2012). However, these results are based on short-term observation using by scuba, laboratory study or intermittently boat tracking with acoustic telemetry. It has been difficult so far to continuously measure activity and movement patterns of red-spotted groupers for long time under the natural conditions. The final goal of our study is to understand behavior and ecology of the red-spotted grouper under the natural condition. In this paper, we applied acoustic acceleration...
transmitters to red-spotted groupers to examine whether the transmitter could detect activity of this species, providing important insights into their movement patterns and activity rhythm.

2. Materials and Methods

A continuous acoustic acceleration transmitter, AccelTag (Thelma Biotel, Trondheim, Norway) was used in this study. The AccelTags were cylindrical shaped (9 mm φ × 39 mm, 7 g weight in air, 66 and 72 kHz frequency) and measures acceleration in three perpendicular axes with 20 Hz sampling rate. Body-fixed acceleration parameters and body angles were derived from acceleration measured by the three axes. To detect the activity, transversal acceleration and tilt angle were used to calculate fish activity meter in the transmitter used in this study. Two contributions (transversal acceleration and tile angle) were summed up after high-pass filtering and finding absolute values and then the compound value was low-pass filtered before converting to signal intervals (Føre et al., 2010). Transversal acceleration fluctuations was subjected to a peak detector with an exponential decay function in order to detect transient increase of transversal acceleration before summing up with tilt angle change (Føre et al., 2010). The exponential decay function was set that an initial value to decrease at a rate of 20% after 10 s. In this paper, data derived from the peak detector were not used for our analysis. Our acoustic transmitters continuously transmitted signal intervals with a range of 1 to 5 sec corresponding to the compound activity parameter. The signal interval becomes 1 sec when the activity intensity is large while it becomes close to 5 sec when the acceleration intensity is small.

Nine wild red-spotted groupers were used in this study. Fish were anesthetized using 0.1% 2-phenoxyethanol solution in a small tank before tagging (Table 1). The acceleration transmitter (AccelTag) was surgically implanted into the fish peritoneal cavity. We also attached external tag dorsal fin in order to identify the individuals. After tagging, total length and body weight were measured. Each tagged fish was released into a holding tank containing fresh bubbling seawater for recovery from the anesthesia. After fish recovery was defined by visual observation, fish were moved to the experimental tank (116 cm in diameter, 550 L in volume) with fresh bubbling seawater, and freely swam in the tank together with several non-tagged fish to make similar condition to the keeping tank. Behavior of each tagged fish was recorded using by a video camera (HDR-CX700V, SONY, Japan) for approximately 1 hour from the top of the tank. The signals of the transmitters were recorded using an acoustic receiver with an omni-directional hydrophone (VR100, VH165, AMIRIX Systems Inc., Halifax, Canada).

The number of tail beat was counted from the video data during the period of 2 seconds while the transmitter was measuring acceleration. In this study, we defined a single tail beat as a movement of caudal fin from the body center to right or left side to the body center. To examine whether the tail beat can reflect output of transmitter as an activity indicator of red-spotted groupers, we compared the number of tail beat with signal intervals of acceleration transmitters. For this analysis, generalized linear model with Poisson error and a log link function was used, and confidence intervals for the number of the tail beat in signal intervals (1–2 and 4–5 seconds) were provided.

3. Results

The red-spotted groupers spent their time near the bottom of the experimental tank. They hardly swam although sometimes they suddenly started to move. When they did not move their caudal fin, the number of tail beat counted was basically small for all fish, and 67.4 ± 13.8% (average ± S.D.: N = 9 fish) of all data for the tail beat was zero (Fig. 1).

The signal intervals were divided to 3 groups: 1–2, 2–4 and 4–5 second in this study. Ratio of the 4–5 second interval was relatively large for all fish (average ± S.D.: 64.0 ± 16.5%, Table 1). The average number of tail beat for nine fish ranged 0.016 to 0.59 when the signal intervals detected were 4–5 second (Table 2). Thus, signal intervals of 4–5 second indicated that red-spotted groupers did not move the caudal fin. Signals at the interval of the 2–4 seconds were less frequently detected than 4–5 seconds (on average 20.2 ± 8.0%, Table 1), and they did not basically move the fin at all even when those signals were detected. On the other hand, the average number of tail beat ranged 1.19 to 4.86 when the signal intervals detected were 1–2 second (Table 2). Therefore, our results showed that the signal intervals distinguished whether red-spotted groupers moved their caudal fin.

Fig. 1 Average percentage of frequency of tail beat from video observation for 9 red-spotted groupers. The error bars is standard deviation of counts of tail beats. The fish hardly swam and did not move their caudal fin during the tank experiment.
Table 1  Summary and detection data of the red-spotted grouper tagged with acceleration transmitters (N = 9). The percentages of signal intervals divided to 3 groups were shown; 1–2 second, 2–3 second and 4–5 second. Total No. is the number of the data detected from acceleration transmitters. The most detected signal interval was 4–5 seconds on average while 1–2 seconds signal intervals were the least detected in 3 groups.

<table>
<thead>
<tr>
<th>Fish ID</th>
<th>TL (cm)</th>
<th>BW (g)</th>
<th>Total No.</th>
<th>1–2 s (%)</th>
<th>2–3 s (%)</th>
<th>4–5 s (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25</td>
<td>210</td>
<td>592</td>
<td>1.7</td>
<td>20.9</td>
<td>77.4</td>
</tr>
<tr>
<td>2</td>
<td>31.5</td>
<td>460</td>
<td>865</td>
<td>26.4</td>
<td>29.5</td>
<td>44.2</td>
</tr>
<tr>
<td>3</td>
<td>27</td>
<td>230</td>
<td>856</td>
<td>10.9</td>
<td>15.3</td>
<td>73.8</td>
</tr>
<tr>
<td>4</td>
<td>21.3</td>
<td>130</td>
<td>585</td>
<td>2.9</td>
<td>19.1</td>
<td>77.9</td>
</tr>
<tr>
<td>5</td>
<td>26.7</td>
<td>240</td>
<td>662</td>
<td>6.3</td>
<td>17.1</td>
<td>76.6</td>
</tr>
<tr>
<td>6</td>
<td>20.5</td>
<td>120</td>
<td>900</td>
<td>19.4</td>
<td>12.7</td>
<td>67.9</td>
</tr>
<tr>
<td>7</td>
<td>21.5</td>
<td>115</td>
<td>703</td>
<td>32.9</td>
<td>33.0</td>
<td>34.1</td>
</tr>
<tr>
<td>8</td>
<td>42.7</td>
<td>1140</td>
<td>449</td>
<td>22.9</td>
<td>25.6</td>
<td>51.4</td>
</tr>
<tr>
<td>9</td>
<td>39.2</td>
<td>870</td>
<td>476</td>
<td>18.4</td>
<td>8.6</td>
<td>73.0</td>
</tr>
</tbody>
</table>

Average 15.8 20.2 64.0
S.D. 10.9 7.95 16.5

Table 2  The average and confidence intervals of tail beat frequency (times/2s) in both of 1–2 second intervals and 4–5 intervals for 9 red-spotted groupers.

<table>
<thead>
<tr>
<th>Fish ID</th>
<th>1–2 s average</th>
<th>1–2 s CI</th>
<th>4–5 s average</th>
<th>4–5 s CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.00</td>
<td>1.25–3.01</td>
<td>0.59</td>
<td>0.52–0.66</td>
</tr>
<tr>
<td>2</td>
<td>1.70</td>
<td>1.53–1.87</td>
<td>0.25</td>
<td>0.20–0.30</td>
</tr>
<tr>
<td>3</td>
<td>1.40</td>
<td>1.18–1.66</td>
<td>0.53</td>
<td>0.47–0.59</td>
</tr>
<tr>
<td>4</td>
<td>1.53</td>
<td>1.01–2.19</td>
<td>0.27</td>
<td>0.22–0.32</td>
</tr>
<tr>
<td>5</td>
<td>1.50</td>
<td>1.16–1.90</td>
<td>0.23</td>
<td>0.19–0.27</td>
</tr>
<tr>
<td>6</td>
<td>1.18</td>
<td>1.03–1.35</td>
<td>0.016</td>
<td>0.0082–0.029</td>
</tr>
<tr>
<td>7</td>
<td>4.87</td>
<td>4.59–5.16</td>
<td>0.25</td>
<td>0.19–0.32</td>
</tr>
<tr>
<td>8</td>
<td>1.85</td>
<td>1.60–2.13</td>
<td>0.32</td>
<td>0.25–0.40</td>
</tr>
<tr>
<td>9</td>
<td>1.73</td>
<td>1.51–1.98</td>
<td>0.20</td>
<td>0.16–0.24</td>
</tr>
</tbody>
</table>

4. Discussion

Our results showed that AccelTags are able to distinguish whether a sit-and-wait predator, the red-spotted groupers, remained still or moved their caudal fins. The movement of the caudal fins, namely the tail beat activity, is closely related to swimming behavior of fish (Kawabe et al., 2003). The video data demonstrated that red-spotted groupers actually showed active swimming behaviors when moving their caudal fins. When acoustic signals in 4–5 second intervals were detected, the numbers of the tail beat for all individuals were less than one during the period of acceleration measurement (two seconds). This indicated that red-spotted groupers remained still. On the other hand, when acoustic signals in 1–2 second intervals were detected, the numbers of the tail beat were more than one during the period of acceleration measurement. This indicated that groupers showed swimming behavior. Signals in 2–4 second intervals were not used to distinguish fish movements because those data might be derived from fish movement as well as the peak detector (exponential decay function). The signals in 2–4 second intervals were detected even if the tagged fish already stopped their movement and the number of tail beat was 0. Thus, if these signal intervals were included in the analysis, we could not divide whether the tagged fish weakly moved their tail compared with 1 second or they stopped.

The number of tail beat in the 1–2 second interval varied within an individual as well as among individuals although we could distinguish whether the tagged fish moved or did not move in all individuals. The variation within an individual was probably caused by how to move their caudal fins because only the number of the tail beat was counted without considering amplitude and intensity of the tail beat in this study. In addition, the variation among individuals might be also caused by the transmitter position in fish body. The transmitter posi-
tions in fish peritoneal cavity were variable among the individuals. Even if the same size of fishes produce the same behavior, their transmitters would provide different acceleration values. There was also the possibility that fish showed different swimming behavior; steady swimming and burst swimming.

Acoustic telemetry with acceleration transmitter allows us to detect activity of the red-spotted groupers. The red-spotted groupers have been considered to show diel movement patterns; they move for foraging at nighttime and the crepuscular time, and do not show large-scale movement in daytime (Itani et al., 2005; Masuda et al., 2012). In addition, it has been known that red-spotted groupers spawned in pairs in June–September (Ukawa et al., 1966; Okumura et al., 2002). It has been difficult to observe or measure such movement and activity patterns under the natural conditions. However, the acceleration transmitter would detect when they show active movement. Long time observation with the acceleration transmitters enables to understand diel and seasonal movement and activity of red-spotted groupers. In this paper, red-spotted groupers were used as a mode species of sit-and-wait type fish. Because other sit-and-wait predators may show similar behavior to red-spotted grouper, it is possible to measure their activity using the acceleration transmitter. Thus this technique can be useful to not only red-spotted groupers but also other sit-and-wait predators.

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References


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超音波加速度発信機を用いた待ち伏せ型捕食者キジハタの活動測定

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