

Possibility of position estimates for bottom-dwelling aquatic animals in a small area using ultrasonic coded transmitters and passive monitoring receivers

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ABSTRACT

The objective of this study is to examine the possibility of position estimates for bottom-dwelling aquatic animals utilizing small areas by the use of ultrasonic coded transmitters and passive monitoring receivers. We measured the relationship between the rate of signal receptions and the distance from each receiver by deploying ten ultrasonic coded transmitters near the bottom in an array of six receivers in a small area (100 x 250 m). We then tested the weighted means analysis and a multiple regression analysis for estimating the transmitter positions. The relationship between the rate of signal receptions and the distance from each receiver were not always linear, probably because of bottom topography, and there were relatively large errors in both analyses. Therefore, for bottom dwelling aquatic animals utilizing a small area, it is better to make detailed three dimensional maps of reception rates and positions of transmitters in order to estimate finer-scale positions of ultrasonically-tagged animals using ultrasonic coded transmitters and passive monitoring receivers.

KEYWORDS: weighted means, multiple regression, centers of activity, position estimates

INTRODUCTION

Long-term monitoring of animal positions lets us know the habitat preference and home range or utilization distribution of targeted animals. This information is very important for effective management of targeted animals because we cannot decide how large the reserve should be or which habitats are to be protected without this information. However, it is very difficult to monitor aquatic animal positions for a long period in water by a conventional visual observation with scuba diving.

Ultrasonic biotelemetry is a widely used method to monitor animal positions in water. With the advent of automated monitoring receivers and coded ultrasonic transmitters, we now can monitor several individuals simultaneously for a long time without actively tracking the animals. However, this technique is only capable of recording the presence or absence of ultrasonically tagged animals.

In recent studies, a method has been developed to estimate short-term centers of activity of migratory aquatic animals using an array of automated monitoring receivers (Simpfendorfer *et al.*, 2002; Mitamura *et al.*, 2005). They estimated centers of activity of migratory aquatic animals based on weighted means of the rate of signal receptions (the rate of actual reception numbers to the ideal maximum reception numbers) at each receiver during a specified time period. This technique is based on the same linear relationship in any direction between the rate of signals received and the distance from a

receiver. However, Simpfendorfer *et al.* (2002) also mentioned that many factors tend to change the linear relationship, including bottom topography, submerged aquatic vegetation, different sensitivities between pieces of equipment, signal overlaps because of large numbers of animals present in an area or short signal-repeat intervals, and noise from biological and human sources. They discussed that even though these factors tended to change the linearity, it did not have very much affect on estimations of activity centers of migratory animals utilizing broad areas; however, it is possible that the factors affect estimations of activity centers of animals utilizing a relatively small area. In particular, signals from tagged animals utilizing a small area and living near the bottom could be largely influenced by bottom topography. Therefore, in order to apply this technique to animals utilizing a small area and living near the bottom, we need to test whether this technique is feasible or not.

In this study, we first measured the relationship in each receiver between the rate of signal receptions and the distance from each receiver by deploying ten transmitters near the bottom in an array of six receivers in a small area (100 x 250 m). We then tested the weighted means analysis for estimating the transmitter positions. Since the result of the estimated positions showed relatively large errors, we then used a multiple regression analysis, a widely-used linear model which examines the

relation of a dependent variable to specified independent variables.

MATERIALS AND METHODS

Study site

We monitored black-spot tuskfish in Urasoko Bay of Ishigaki Island (Fig.1). The bay is covered by coral reefs with an adjacent sandy bottom. The area with coral reefs is less than 10 m in depth; the sandy area is from less than 10 m to more than 30 m in depth (Fig.1). The study site has a deep sandy bottom with patched corals surrounded by coral reefs (Fig.1).

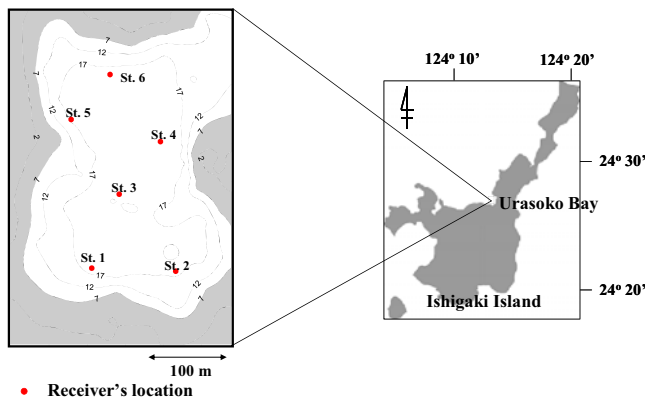


Fig.1. The study site and receivers' locations. The lines with numbers in the map show depth contours. The shaded area in the map represents a coral reef.

Coded ultrasonic transmitters and automated monitoring receivers

We used coded ultrasonic transmitters (V9P-2H, Vemco Ltd., Canada) that were 9 mm in diameter and 46 mm long with a weight of 2.9 g. in water. They transmit complex codes of six pulses. This allows for the identification of potentially up to 256 individuals using the same frequency. Transmitters transmit a signal once every 60 to 180 seconds with an expected battery life of 150 days. The signals from the transmitters were detected using automated monitoring receivers. The receivers recorded the ID number, date and time when a transmitter existed within approximately 150 m of the receiver.

Relationships between signal receptions and distance from a receiver

We deployed six automated monitoring receivers (VR2, Vemco Ltd., Canada) close to each other so that the detection ranges of the receivers overlapped (Fig. 1). In order to measure a relationship between the rate of signals received and the distance from a receiver, we deployed ten transmitters 1 m above the sea bottom for 20 hours. For each receiver, we calculated a relationship between the reception rate and the distance from a receiver, and a relationship between the reception rate and the coordinates of transmitter positions. The relationship between the reception rate and the coordinates of transmitter positions were illustrated by showing 20% and 50% areas of reception rate in the study site using Surfer(R) Version 8.0 (Golden Software, Inc.).

Calculation of position estimates

We subjected the data to a weighted means algorithm and a multiple regression algorithm in order to test the position estimates of the transmitters. Table 1 shows the formula of the two methods. We also calculated position fix accuracies, or distances between estimated positions and real positions measured by GPS. We then calculated the mean and standard deviation of the position fix accuracy of each analysis.

RESULTS

Relationships between signal receptions and distance from a receiver

Reception rates tended to reduce between 100 m and 200 m from a receiver, but there were samples in which there were no reception at less than 100 m distance from a receiver (Fig.2; St. 4, St. 6). The reduction of reception rates differed depending on directions from receivers especially in St. 3, St. 4, St. 6 (Fig.3).

Table 1. Formula of a weighted means algorithm and a multiple regression algorithm.

Weighted means analysis	Multiple regression analysis
$X' = R_1X_1 + R_2X_2 + \dots + R_nX_n$	$X' = a_0 + a_1R_1 + a_2R_2 + \dots + a_{n-1}R_{n-1}$
$Y' = R_1Y_1 + R_2Y_2 + \dots + R_nY_n$	$Y' = b_0 + b_1R_1 + b_2R_2 + \dots + b_{n-1}R_{n-1}$
n=the number of receivers in the array <i>R_i</i>=the <i>i</i>th receiver's reception rate of the total reception during a set time period <i>X'</i>=estimated X coordinate <i>X_i</i>=the X coordinate of <i>i</i>th receiver <i>Y'</i>=estimated Y coordinate <i>Y_i</i>=the Y coordinate of <i>i</i>th receiver	n=the number of receivers in the array <i>R_i</i>=the <i>i</i>th receiver's reception rate of the total reception during a set time period <i>a_i</i>, <i>b_i</i>=parameters <i>k</i>=the number of sample data <i>X'</i>=estimated X coordinate <i>Y'</i>=estimated Y coordinate
NOTE: Parameters <i>a_i</i> and <i>b_i</i> are fixed by finding the minimum of the sum of the squares of real data minus estimated data.	

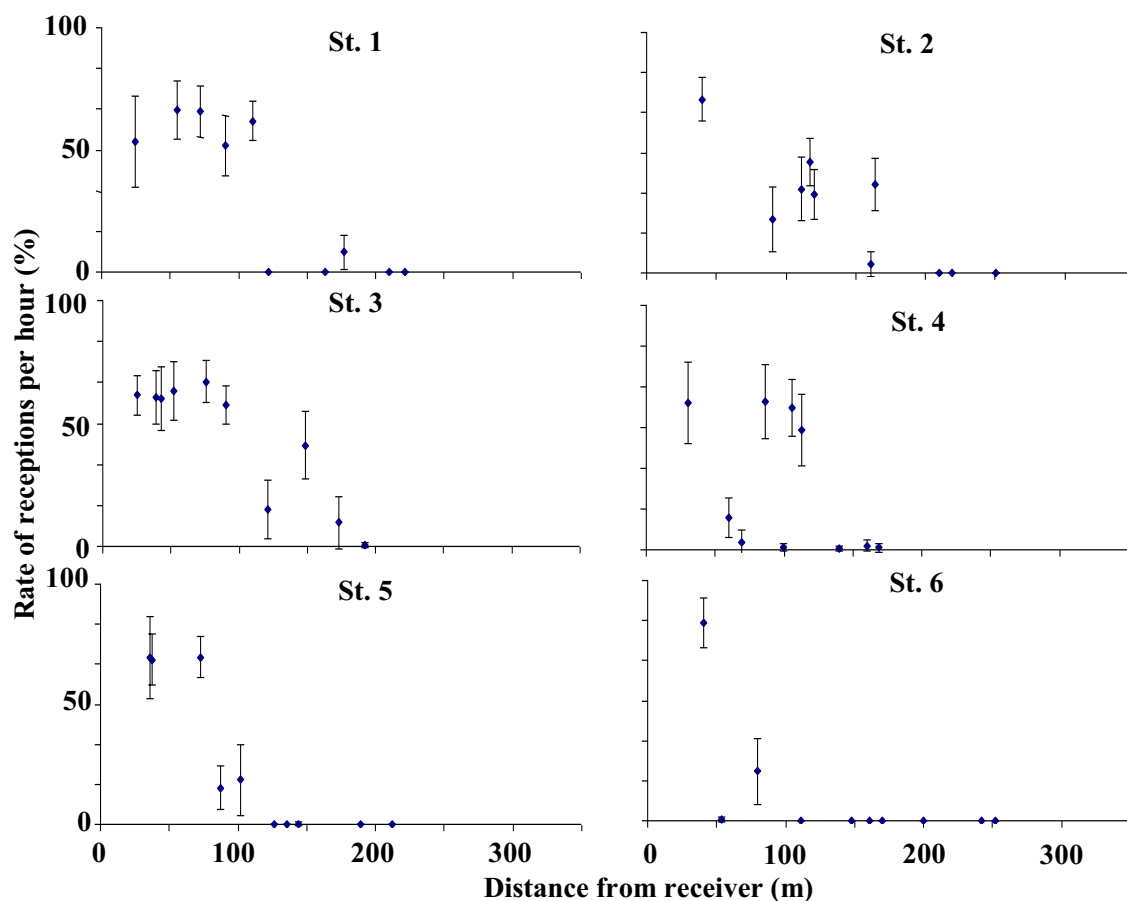


Fig.2. Relationship between the rate of receptions and the distance from a receiver. Squares represent mean hourly values for 20 hours and error bars represent standard deviation.

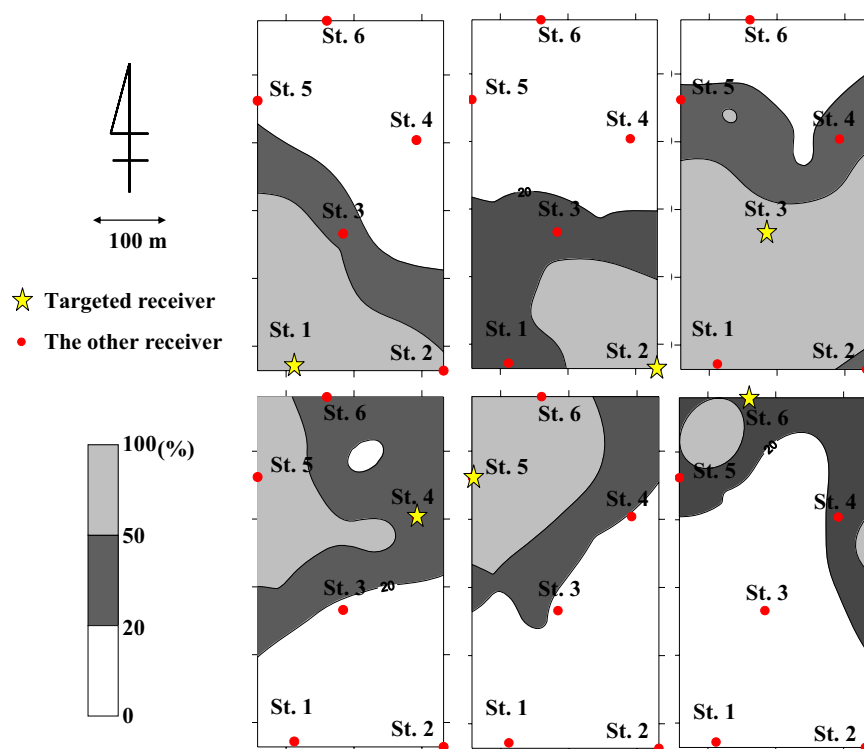


Fig.3. The estimated area of 20% and 50 % receptions per hour of each receiver.

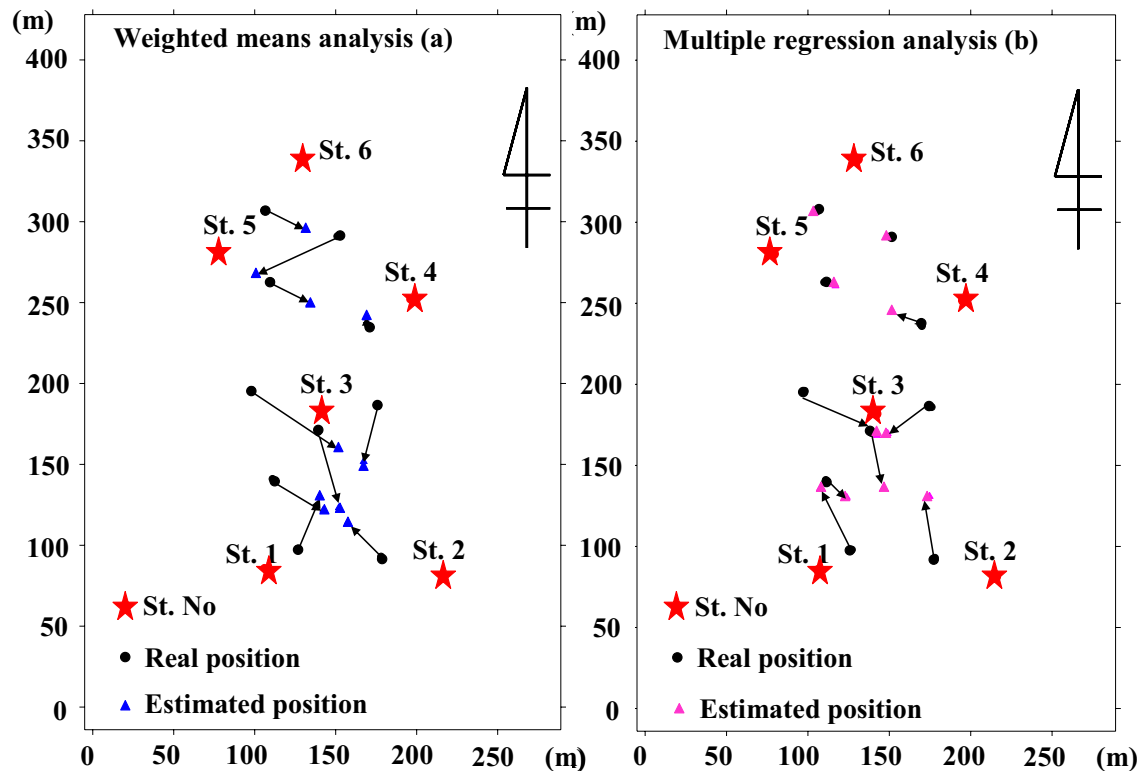


Fig.4. Position estimates by a weighted means analysis (a) and by a multiple regression analysis (b).

Position estimates of a weighted means analysis and a multiple regression analysis

The real positions measured by GPS are also shown in Fig.4. The position fix accuracy of positions estimated by the weighted means analysis was 35.2 ± 19.2 m; the position fix accuracy of positions estimated by the multiple regression analysis was 24.9 ± 21.0 m. Transmitters deployed around St. 1, St. 2 and St. 3 were likely to be estimated inside of a triangle of St. 1, St. 2 and St. 3.

DISCUSSION

In this study, the position fix accuracies of weighted means analysis and multiple regression analysis were 35.2 ± 19.2 m and 24.9 ± 21.0 m, respectively. Since the distance from each receiver to the nearest receivers were approximately 100 m and we deployed the transmitters within approximately 100 m x 250 m, these position fix accuracies seem to be relatively large to examine fine scale movements of bottom-dwelling animals.

We found that the relationship between the rate of reception and the distance from a receiver differs depending on the direction from the receiver, especially in St. 3, St. 4 and St. 6 (Fig. 2; Fig 3). This suggests that, in this study site, there were less linear relationships on which the weighted means analysis was based.

There are lots of possible factors that reduced the linear relationship: bottom topography, submerged aquatic vegetation, different sensitivities

between pieces of equipment, signal overlaps because of large numbers of animals present in an area or short signal-repeat intervals, and noise from biological and human sources (Simpfendorfer *et al.* 2002). There was no notable aquatic vegetation that could reduce the reception rate of receivers in this study site (personal observation). Different sensitivities between pieces of equipment would be less likely to affect the different sensitivities in different directions from a receiver. Since we used the transmitters that transmit signals infrequently (they transmit signals once every 60 to 180 sec), there would be less signal overlaps (Vemco Ltd. Website: <http://www.vemco.com>). Usually noise, even if it's from human or aquatic animals, is less likely to continue for a long time. In this study, there were almost no detections for 20 hours in some cases even though the distance between the receiver (St. 4, St. 6) and a transmitter were less than 100 m (Fig. 2). Therefore, it is less likely that noise reduced the linear relationship. Considering what I mentioned, it is more likely that there were less linear relationships because of bottom topography. We deployed transmitters near the bottom; the bottom depth was slightly higher between St. 2 and St. 4 (Fig. 1). Considering that line-of-sight between the receiver and the transmitter is needed to receive the signals, probably this higher bottom depth blocked the receivers from receiving the transmitter signals even though they were relatively close to each other. Thereafter, less linear relationships between the

reception rates and the distance from the receivers occurred.

The weighted means analysis is based on the linear relationship in all directions between the reception rate and the distance from a receiver. Since there was less linear relationship, probably because of bottom topography, this method is not the best way to monitor animal positions in this study site. Actually, some transmitters positions around St. 1, St. 2 and St. 3 were estimated inside of a triangle of St. 1, St. 2 and St. 3 (Fig. 4). The multiple regression analysis is also based on the linear relationship between the reception rate and the distance from a receiver. If a major factor that reduces the reception rate were different sensitivities of pieces of equipment or vegetation near the receiver which only reduce a slope angle of the linear relationship, this analysis could calibrate the estimated positions. In a case like this study: the bottom was not flat and target animals live near the bottom, one possible method to estimate finer-scale animal positions is to make detailed three dimensional maps of reception rates in each receiver by deploying transmitters all around the study site. Then, we would estimate the positions by overlapping all the receivers' maps of reception rates.

A lot of biotelemetry studies have been conducted on aquatic animals living near bottom with small home ranges, such as wrasse (Topping *et al.*, 2005), and kelp bass (Lowe *et al.*, 2002). Understanding of their fine-scale positions and habitat preferences are clarified by active tracking and radio acoustic positioning (RAP) systems (Voegeli *et al.*, 2001). Active tracking is one solution, but monitoring periods are usually short since it is labor intensive. The RAP system can locate the tagged animals by calculating through the lags of arrival time of a signal to more than three different receivers. This method tells us very fine-scale positions of animals; however, this system is relatively expensive and its monitoring range is limited. Biotelemetry using automated monitoring receivers and coded ultrasonic transmitters lets us monitor targeted animals in a wider range and for a long time, as well as being relatively less expensive. Therefore, using this equipment to clarify fine-scale positions of animals is very useful for a lot of researchers. In this study, we found that it was not always possible to use a weighted means analysis and a multiple regression analysis where: the bottom was not flat; targeted animals utilize small areas and live near bottom. However, making detailed three-dimensional maps of reception rates all around the study site will probably make progress in estimating the positions of bottom dwelling animals utilizing a small area by using automated monitoring receivers and coded ultrasonic receivers.

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