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Preliminary result of Pop-up archival tagging for Atlantic bluefin tuna (*Thunnus thynnus*) released in the northeastern Atlantic Ocean

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Summary

We report the preliminary analysis of migration of Atlantic bluefin tuna which was tagged and released from the area off Ireland. This individual was caught on 29th September 2007 and released after the attachment of popup archival tag (PAT) at the location (48-16N, 11-50W). The length estimated by eye was 160cm (FL). On the 29th March 2008, this tag was popped off 6 months after the release as programmed, and transmitted the data for past 6 months. This individual conducted trans-Atlantic movement from the eastern to the western north Atlantic. Based on the distinct temporal pattern of maximum diving depth and average temperature (both on daily basis), we identified three phases in movement pattern as follows. In the first phase (9/29-1/26), this individual stayed in the relatively limited area with shallow vertical movement in the warm water, and embarked on the long distance movement to the west with deep vertical movement in the cold water in the second phase (1/27-2/6), and it stopped the large movement and stayed in the terminal area with shallow vertical movement in the cold water in the third phase (2/7-3/29). The oceanographic feature may be associated with this change of behavior, which needs to be confirmed in the future. In this result, the link between the eastern foraging ground and the western breeding area was not confirmed but the intercommunication between east and west in the Atlantic was supported.

Introduction

Many tagging research for Atlantic bluefin tuna (*Thunnus thynnus*) using popup archival tag (PAT) has been conducted in the northwestern Atlantic. The trans-Atlantic movement from the west to the east area has been indicated by many studies (Lutcavage *et al.* 1999, Block *et al.* 2001). However, the attempts that release the fish from the eastern area are relatively small. Recently, Stokesbury et al. (2007) showed the trans- Atlantic movement from the east to west by tagging the fish from off the coast of Ireland.

In this document, we introduce the additional information on the movement of this species released in the northeastern Atlantic.

Materials and methods

On 29th September 2007, one pop-up archival tag (PAT: Microwave Telemetry Inc., PTT-100) was attached to a bluefin tuna (160cm FL: indicated as "# 67681" thereafter) and released in the northeastern

Atlantic (48-16N, 11-50W). At tagging, # 67681 was fixed with the head hoisted by the large gaff and the dart which was connected with PAT body via tether, was inserted into the dorsal muscle under the midpoint between the first and second dorsal fin from the side of vessel. This tag was set to pop off 6 months after the release and actually popped off on 29th March 2008 as programmed.

Geo-location of the tag during days at liberty was initially provided from the manufacture (Microwave Telemetry Inc.). They were estimated from estimated time at sunrise and sunset. However as is usually happens, estimated positions (latitude, in particular) of tag were very erroneous. This is substantial around equinox. Therefore we used UKFSST; a R package to estimate geolocation through unscented Kalman filter (Lam et. al 2008) to improve position estimates by including temperature information. Due to time constraint, for sea surface temperature we used daily average of temperature as an proxy of SST, while this would not be problem since in most of the case the individual stayed shallower water during the tag attached.

Using the filtered data of position, we plotted the estimated point horizontally. In addition, we extracted the maximum diving depth for each day and calculated the daily average of temperature that this individual experienced.

Results and discussion

The horizontal movement trajectory of # 67681 estimated from unscented Kalman filter was shown in **Figure 1**. Around equinox, large correction of position from light based position estimates in latitude was observed. At a large scale, # 67681 conducted trans-Atlantic movement from autumn to spring with different pattern of movement. After released at in the area off Ireland (48-16N, 11-50W), it stayed about the area (40-50° N 10-20° W) during half of the days at liberty (9/29-1/6) and then began the travel to the west. In this movement, # 67681 moved directly to the west (1/7-2/12) and then changed the direction to the south (2/13-17). Reaching at the area (around 40° N, 38 ° W), it moved to the west again (2/18-2/23). After that, this individual stayed in relatively limited area (2/23-3/29). The change of temperature, with which this individual experienced, corresponded to this movement pattern to some extent.

Figure 2 shows the change of representative SST (smoothed by day) together with predicted one during the day at liberty. SST gradually descended from18.8 to 15.5 ℃ (9/29-1/7) and then rapidly descended to 12.6℃ and remained in the relatively stable range (1/8-2/12) and then rapidly ascended to 17.4℃ (2/13-2/23) and then fluctuated largely (2/24-3/29).

Based on the movement pattern, we tentatively divided the movement into 3 phases (1st residence: 9/29-1/6, traveling period: 1/7-2/23, 2nd residence: 2/24-3/29). Data on the daily maximum diving depth and daily average temperature was calculated using raw data and divided into each phase. **Figure 3** shows the depth frequency in percentage by class for each phase. It suggests that diving depth in phase 1 tends to be shallower than 200m except one dive to 785m and most diving behavior was conducted within 0-100m. However, in phase 2, the maximum diving depth shifted to deeper (100-300m) and then the diving depth shifted to shallower depth again in phase 3. **Figure 4** shows the temperature frequency in percentage by class for each phase. It suggests that #67681 experienced warmer temperature higher than 15°C in phase1 and then moved in the cooler water (mainly cooler than 15°C) in later phase. In phase3, the temperature that this individual experienced became cooler than that in phase2. As a result of comparing the depth distribution between night (18:00-6:00) and day (6:00-18:00) for each phase, temporal difference was observed (**Figure 5**). In phase 1, difference between night and day was small and depth distribution ranged mainly from 0 to 100m. In phase 2, nocturnal depth distribution strongly biased to shallow water (<50m) while diurnal depth range shifted to deeper water than that in phase1. In phase 3, difference between night and day became small again except for the depth frequency from 0 to 50m, in which range the frequency of diurnal observation exceeded that of nocturnal observation.

Depth distribution of bluefin tuna (Atlantic ; *Thunnus thynnus* and Pacific; *Thunnus orientalis)* is known to link to foraging activity (Rooker *et al*. 2007) and to change spatiotemporally according to ambient environment (Wilson *et al*. 2005 for Atlantic bluefin tuna, Kitagawa *et al*. 2000 for Pacific bluefin tuna). This tracking data of #67681 showed that Atlantic bluefin tuna conducted transatlantic movement through various environments changing its diving behavior, with small oscillation movement during residency period and large oscillation movement during long-distance movement period. Stokesbury et al. (2007) reported similar change in diving pattern for individual which conducted trans-Atlantic movement. This pattern may be correlated with the temperature depth profile in each passing point and/or with bathymetric feature. At present, it is unknown what factor caused the change of its behavior both in horizontally and vertically for this individual. In the next step, we are going to examine the movement pattern more quantitatively and evaluate the association with environmental data in detail.

Acknowledgements

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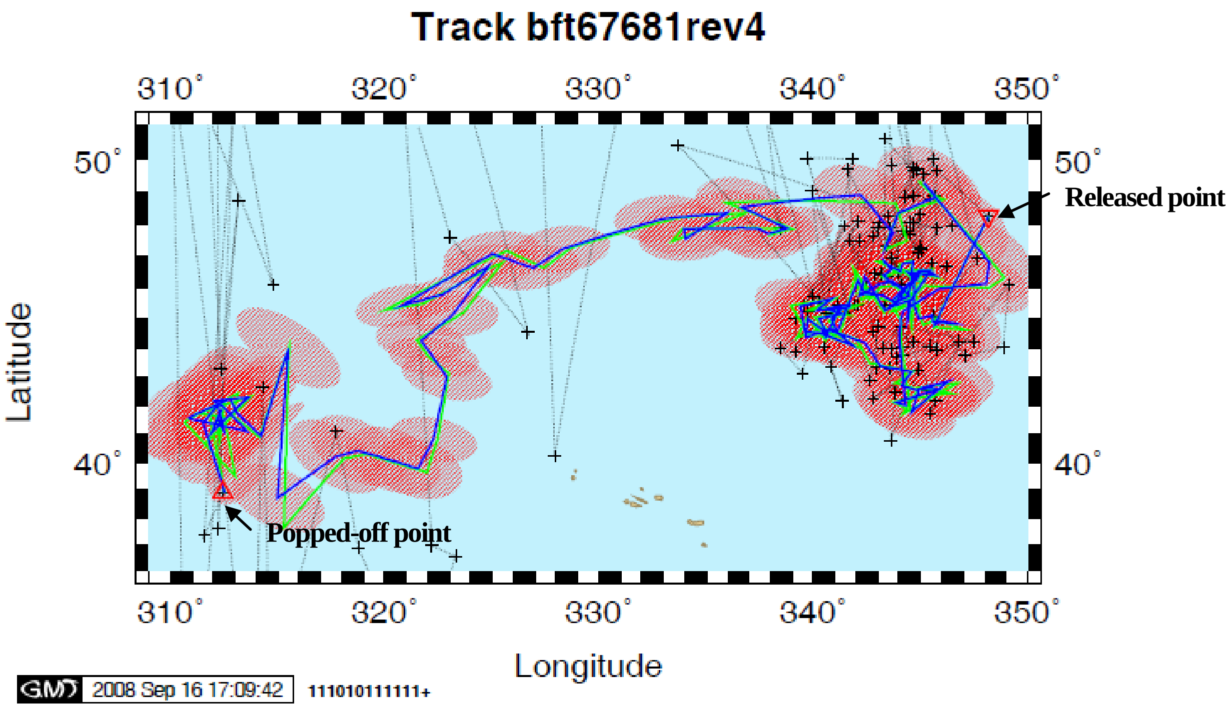


Figure 1. Movement trajectory of #67681. Black solid line with "X" represents light based daily position. green line represents most probable track which is presented together with confidence bounds (red shaded area)

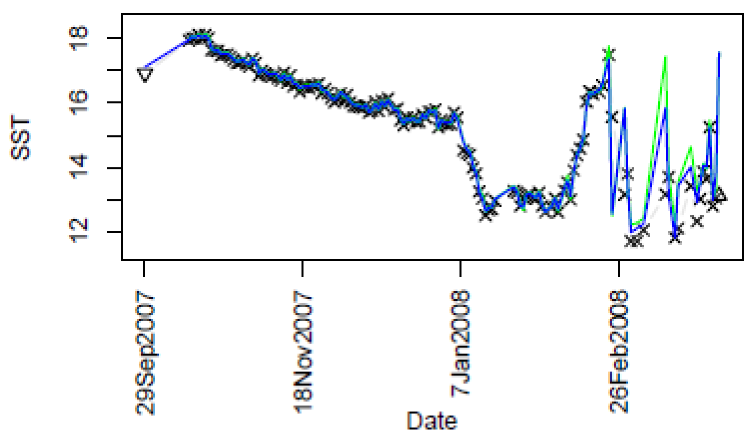


Figure 2 The change of SST(daily) during the period at liberty. "X" represents observed (daily averaged) SST. Blue line represents predicted SST by UKFSST. Green line represents most probable SST by UKFSST

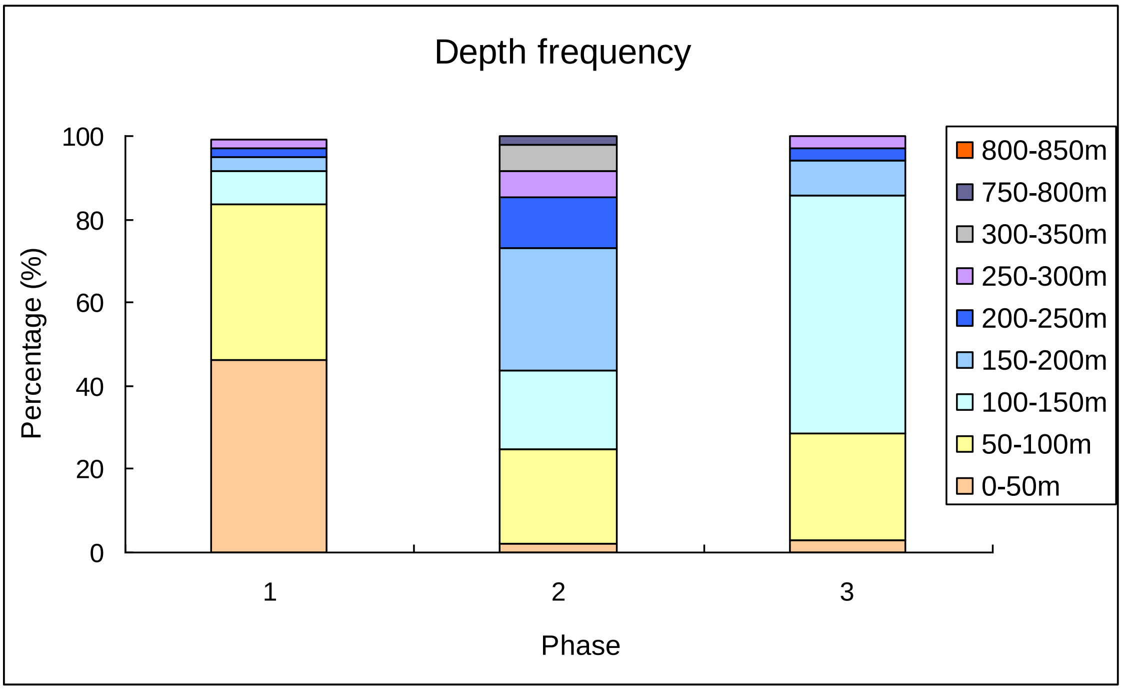


Figure 3. The percentage of depth frequency for each class by phase.

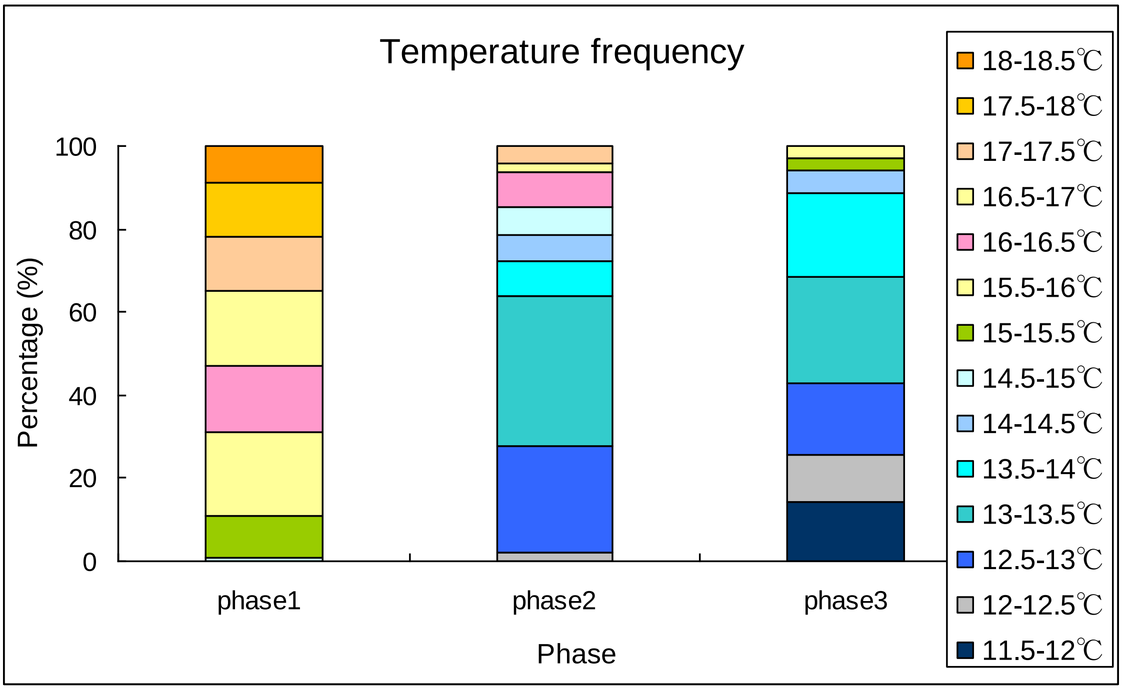
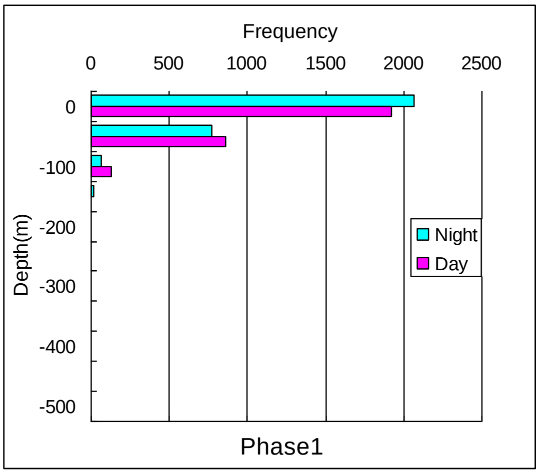


Figure 4. The proportion of temperature frequency for each class by phase.

(a)



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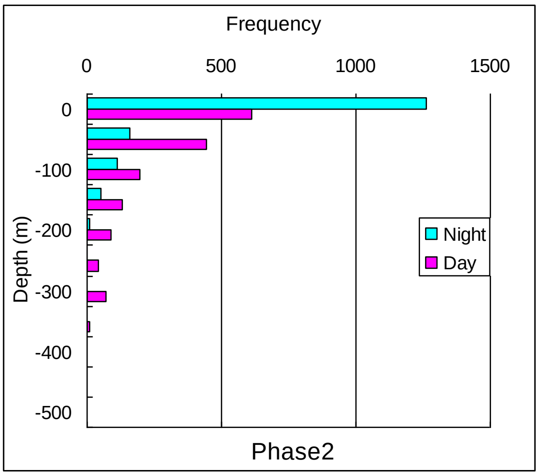

(c)

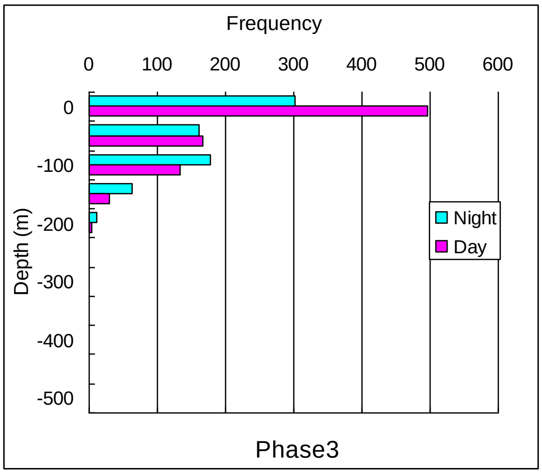

Figure 5. Depth frequency of night and day for each phase. (a) for phase1, (b) for phase2 and (c) for phase3.