Characterizing activity patterns of Pacific halibut with accelerometer data from Pop-up Satellite Archival Tags

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Introduction

Pacific halibut (*Hippoglossus stenolepis*)

- One of the world's largest flatfish species
- High-value fisheries in the north Pacific Ocean
- Ambush predators; may remain motionless on the seafloor for extended periods of time
- Information on activity patterns needed for assessing survival, vulnerability to fishing gear, movement, and habitat utilization

Depth-based activity from archival tags

- Strongly diel during summer, but lack of clear patterns during winter (Scott et al., 2015)
- Sedentary behavior difficult to distinguish from movement at a constant depth

Acceleration-based activity from PSATs

- A PSAT attached with dart and tether floats above a stationary halibut in a vertical orientation
- When the fish starts to swim, drag forces switch the PSAT orientation from vertical to horizontal
- Physically recovered PSATs with accelerometer data (Nielsen and Seitz, 2017) indicate that tilt of the PSAT corresponds to depth-based evidence of activity

Study objectives

- Confirm that tilt measurements from PSATs attached with a dart and tether provide information on halibut activity
- Develop algorithms for summarizing tilt data for satellite transmission
- Characterize activity patterns based on tilt data

Methods

Tag types

- Wildlife Computers miniPAT (WC). Tri-axial, 1 hz
- Maritime bioLoggers MBLog MK1 (MB). Tri-axial, 50 hz, attached to Desert Star SeaTagMOD for field study

Laboratory studies

- Visual confirmation of PSAT orientation during swimming
- Collect high-resolution (50 – 100 hz) acceleration data from rigidly mounted tags for tail beat frequency comparisons
- Assess effects of tidal currents on tilt of tag on stationary fish

Field study

- Port Frederick, Alaska, summer 2015
- 6 halibut (82 - 147 cm)
- 3 WC tags (1 hz), 15 cm tether
- 3 MB tags (50 hz), 5 cm tether
- 3 week deployment
- Physical recovery of tags with Argos goniometer

Analyses

- Link tilt values to change in depth to validate activity
- Develop algorithms for transmitting tilt data from WC tags (1 hz)
- Characterize activity patterns of wild fish

Results

Laboratory studies

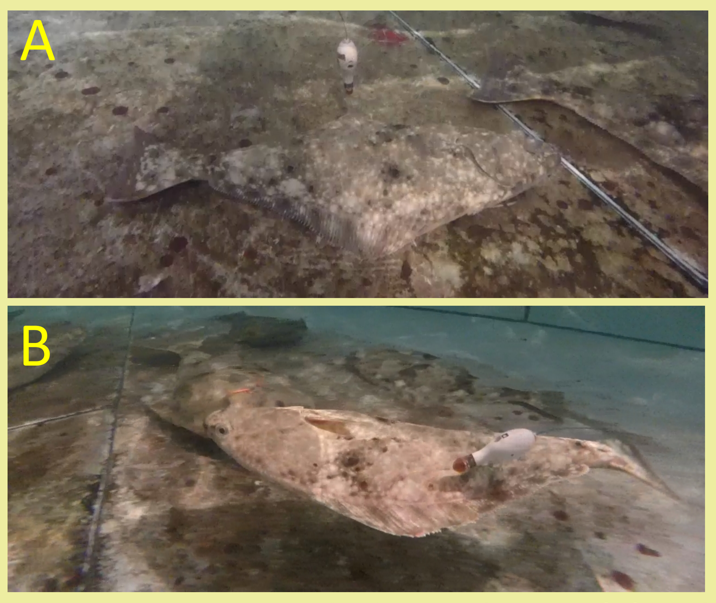

Figure 1. PSAT vertical while sedentary (A) and horizontal while swimming (B).

Scan QR code to watch video of PSAT motion during movement initiation on your own device (16.8 mB)

kingfishermarineresearch.com/resources/Videos/PSAT_KD.mp4

PSAT algorithms

1. "Knockdown": change in vertical (tilt) orientation > 0.5 g within 10 second window
   - Movement indicators (sum of knockdowns per time bin)
   - Robust to tidal influence
2. "% Time tilted": time that PSAT was tilted > -0.75 g
   - Duration of movement events (% time tilted per time bin)
   - Identify unrealistic tag behavior for mortality classification
   - Some risk of noise from tidal influence in areas with tides

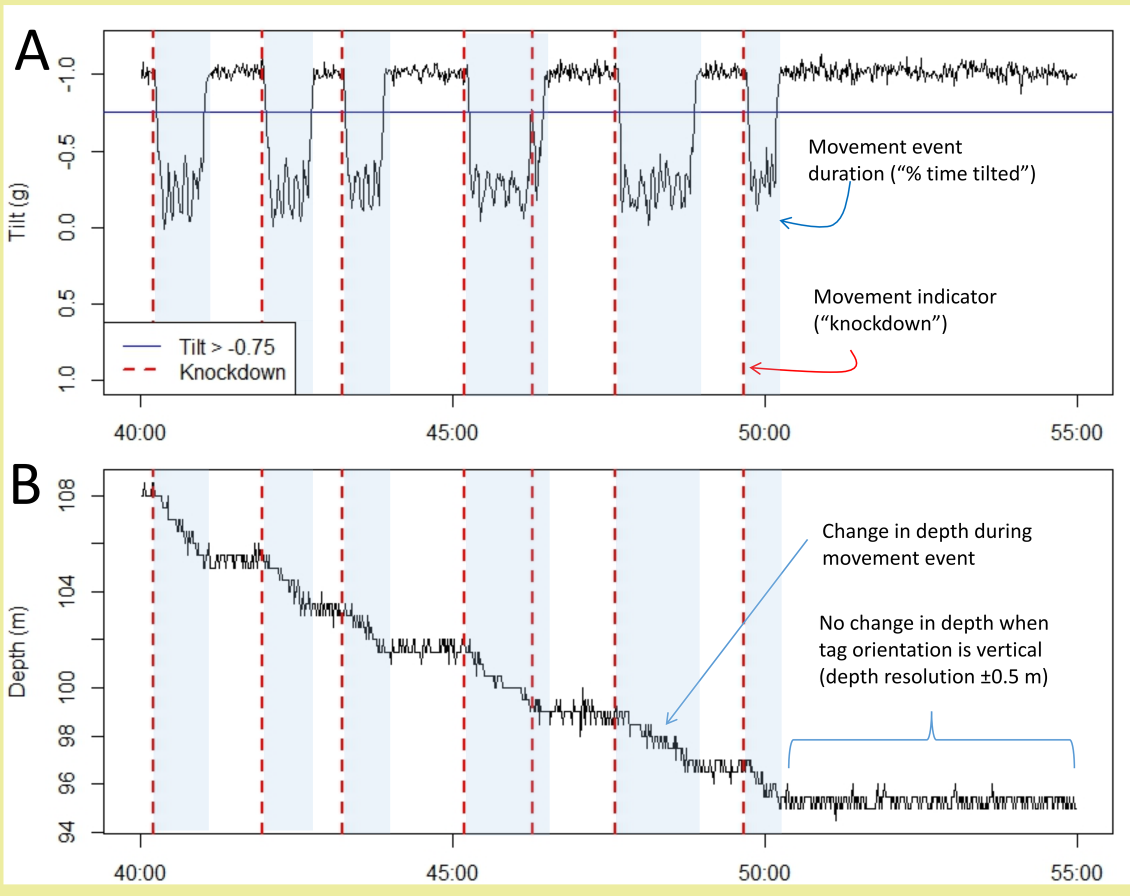

Figure 2. PSAT "knockdown" and "% tilt" algorithms developed to summarize activity for WC (1 hz) PSATs (A) occur simultaneously with changes in depth (B) for a free-ranging halibut.

Behavior types

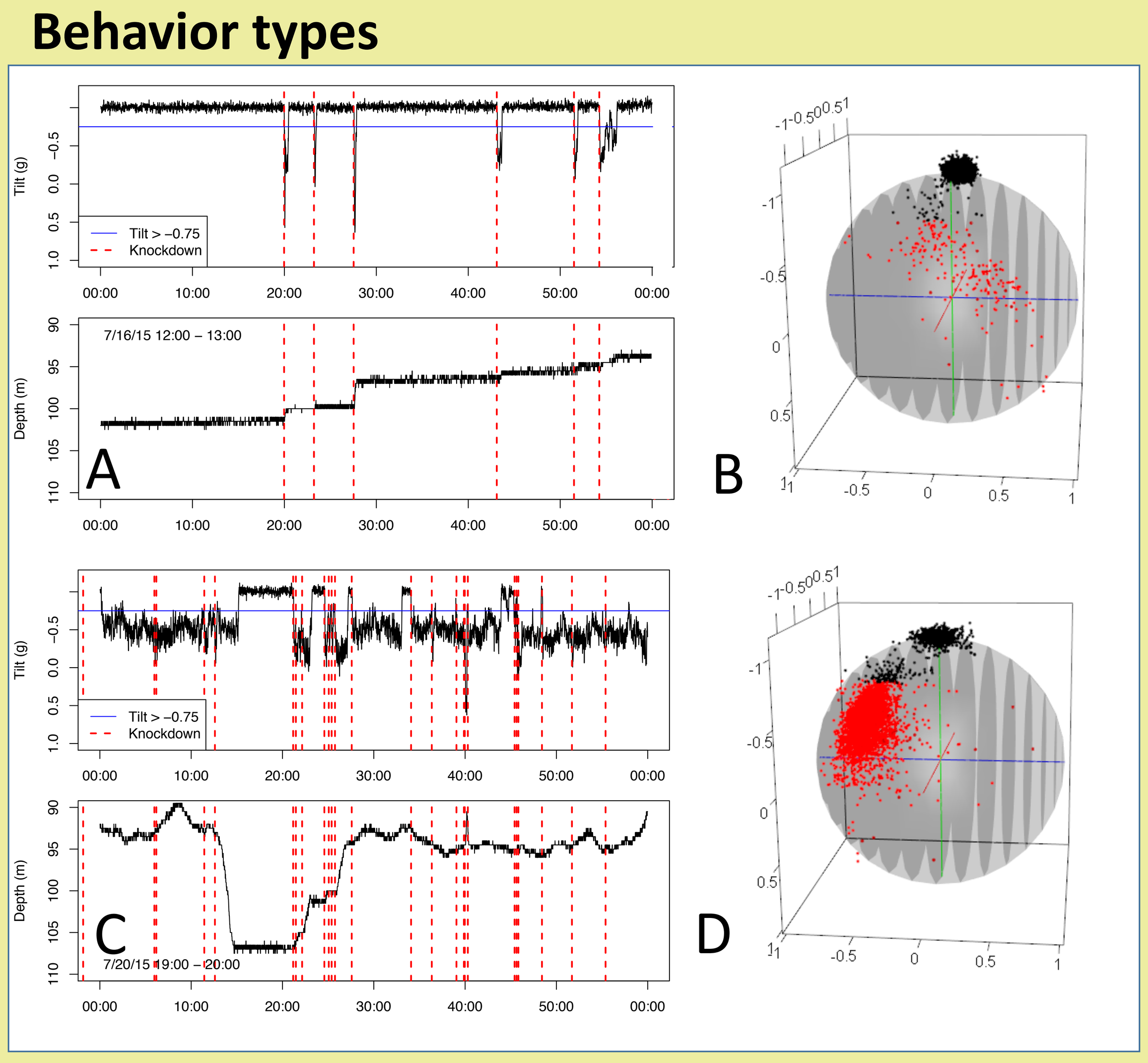

Figure 3. Two behavioral patterns observed in 1hz PSAT acceleration data from the same wild fish. A) "Hopping" behavior, with small numbers of knockdowns and very low values of % time tilted. 3D plots of tri-axial acceleration data (red points: tilt > -0.75, black points: tilt < -0.75) indicate a possible twisting motion of the PSAT during starts and stops (B). C) A sustained swimming pattern, with high numbers of knockdowns and high % time tilted. Tri-axial acceleration data indicate movement of the PSAT along one plane as the fish swims (D).

Behavior from PSAT algorithms

- "Hopping" behavior at night (knockdowns but very low tilt)
- Sustained swimming during day (high knockdowns and high tilt)
- Different foraging strategies?

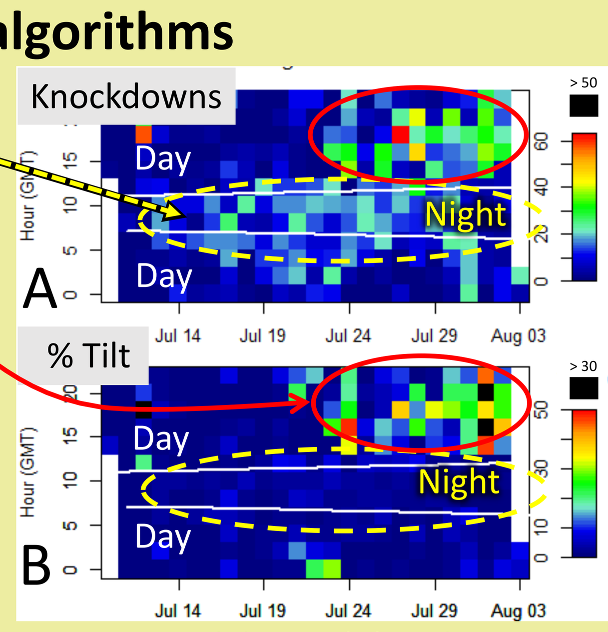

Figure 4. Knockdowns (A) and % time tilted (B) for a free ranging fish (WC PSAT).

Behavior from high-resolution data

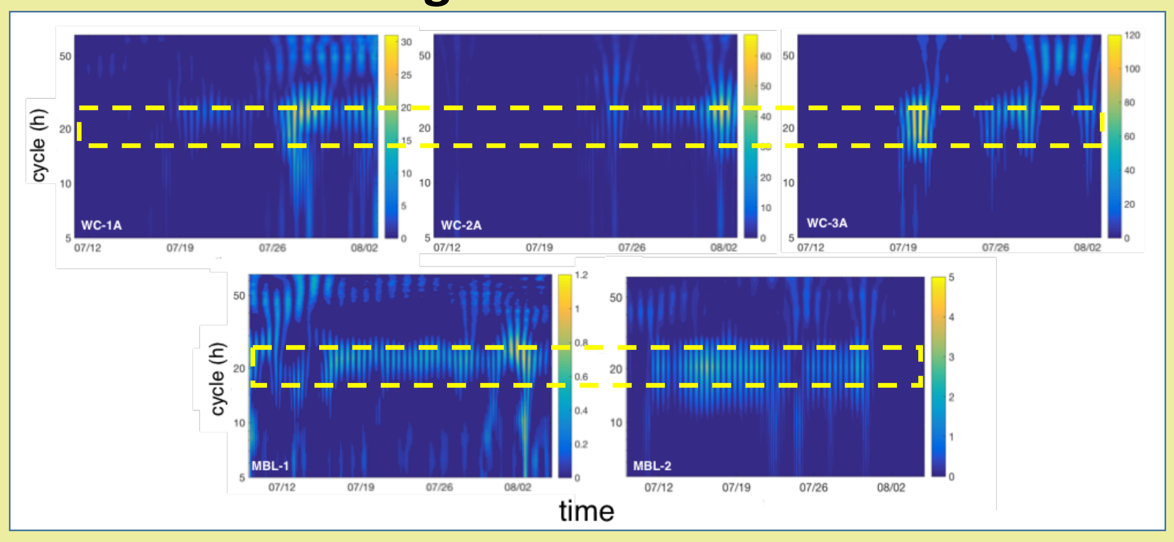

Figure 5. Wavelet analysis of 1 hz (top) and 50 hz (bottom) accelerometer data for free ranging fish indicates strong diel activity patterns. Dashed yellow polygons indicate dominant cycle of 18 – 24 hours.

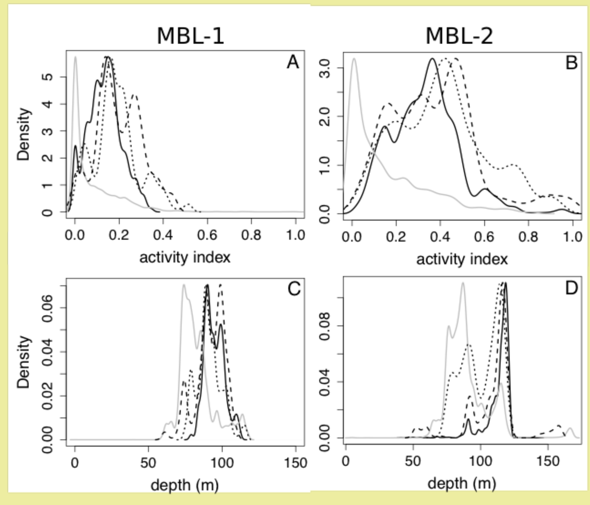

Figure 6. Distributions of activity (A,B) and depth (C,D) for two Pacific halibut (MB 50 hz tags) during daylight (light grey), night (black line), dusk (dashed) and dawn (dotted) indicate a reduced activity in shallow water during daylight hours.

Conclusions:

- At least 3 activity patterns from PSAT tilt data:
  - Stationary
  - "Hopping"/ low activity
  - Sustained swimming/ high activity
  - Difficult to detect these patterns with depth alone, especially in flat topography
- Strong diel patterns during summer
- PSAT algorithm or physical recovery after pop-up with use of Argos goniometer
  - No need to recapture fish
- Caveats:
  - Potential for noisy tilt values in high current areas
  - Downward swimming can be under-detected

Applications:

Halibut bycatch mortality

Survival

Mortality

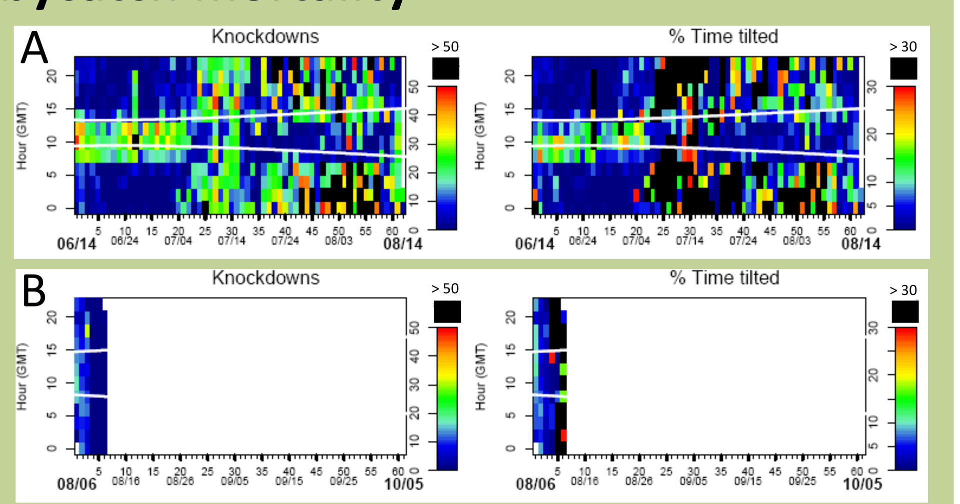

Figure 7. Example of halibut survival (A) and mortality (B) following release from trawls in the Bering Sea (60 day PSAT deployment). The surviving fish was moderately active at night initially, but switched to high activity levels during the day. For the fish that did not survive, activity was very low during the first three days and knockdowns ceased three days prior to premature tag release. High tilt values during the last 3 days were most likely produced by the action of scavengers feeding on the carcass.

Movement states for geolocation models

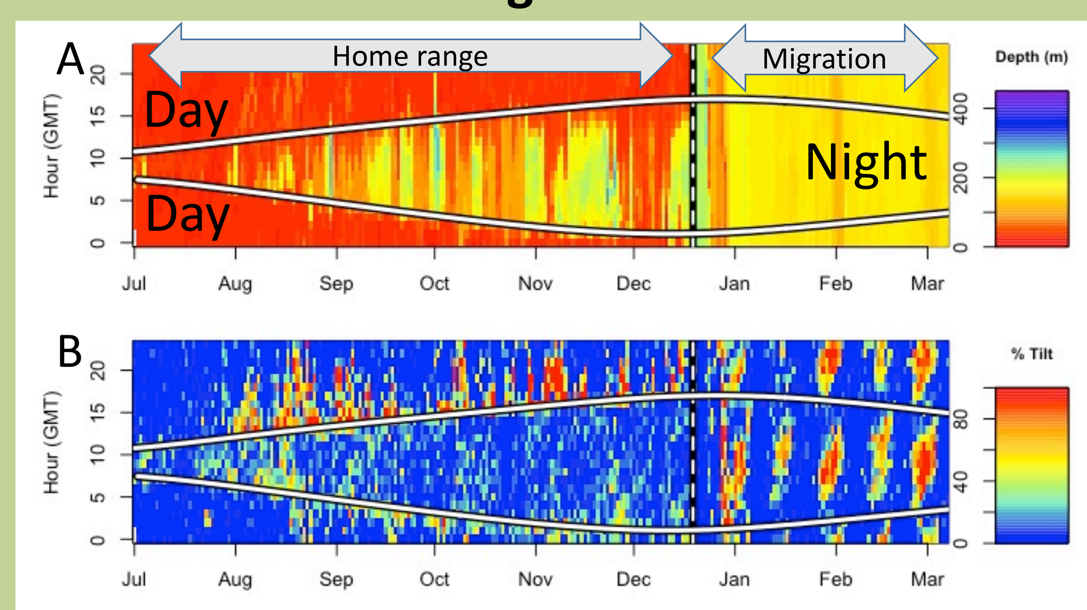

Figure 8. Depth (A) and % time tilted (B) data used to classify summer home range (diel, July – December) and winter migration (tidal, Jan - March) movement states for use in geolocation models. Migration began Dec. 21 based on depth and temperature records (Nielsen and Seitz, 2017).

Future research:

- Identify halibut spawning behavior (50 hz)
- Develop PSAT algorithms for other fish species

Literature cited

Nielsen, J. K., and Seitz, A. C. 2017. Interannual site fidelity of Pacific halibut: potential utility of protected areas for management of a migratory demersal fish. ICES Journal of Marine Science: https://doi.org/10.1093/icesjms/fsx040.

Scott, J., Courtney, M., Farrugia, T. J., Nielsen, J. K., and Seitz, A. C. 2015. An approach to describe periodic behavior of Pacific halibut. Journal of Sea Research: http://dx.doi.org/10.1016/j.seares.2015.1006.1003.