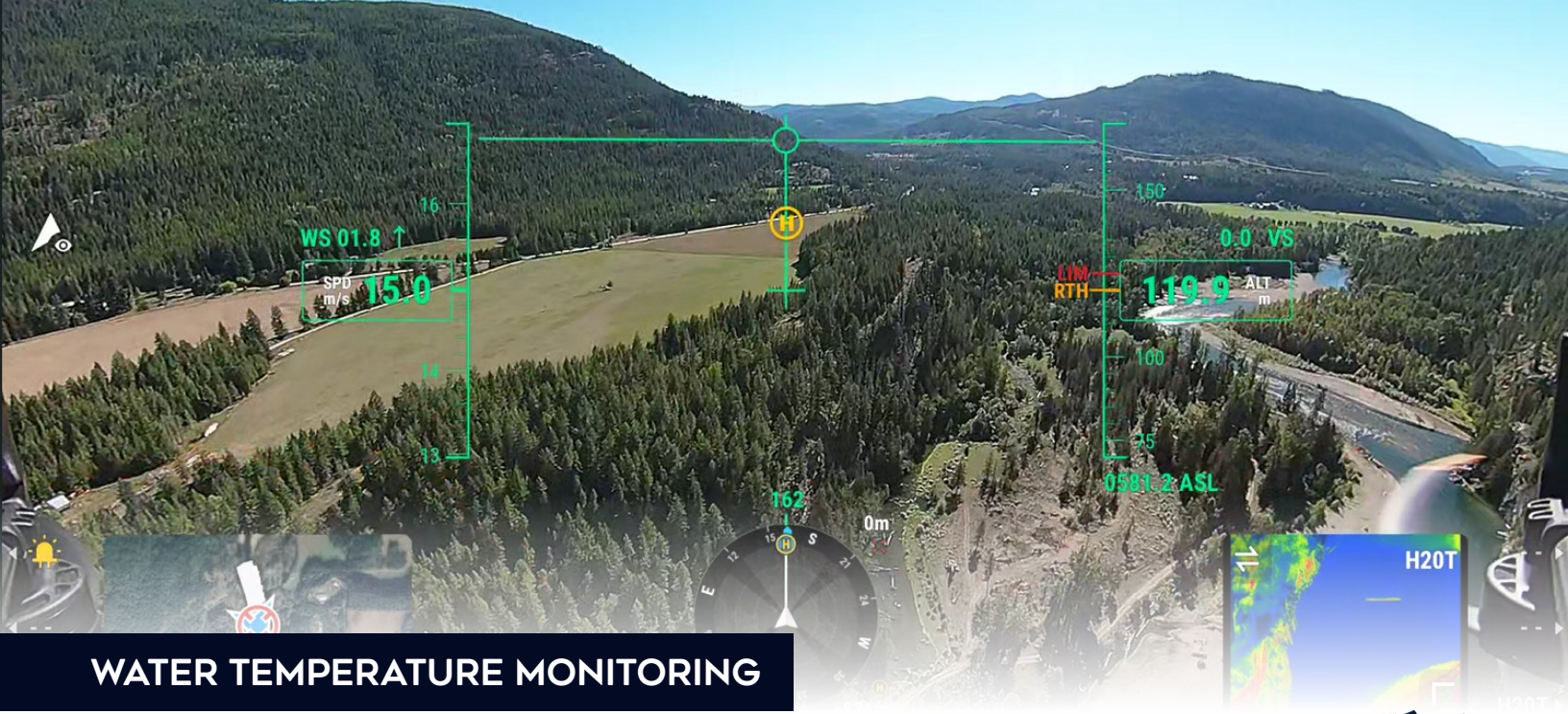

WATER TEMPERATURE MONITORING

REMOTELY PILOTED AIRCRAFT SYSTEM

PACIFIC SALMON FOUNDATION

Water temperature monitoring in streams using Remotely Piloted Aircraft Systems (RPAS; i.e., drone) is an effective and emerging method for capturing high-resolution spatial patterns of water temperature across the stream surface. RPASs equipped with thermal infrared (TIR) cameras can rapidly survey streams, providing detailed thermal maps that are difficult to obtain using traditional in-stream sensors. This approach is helpful for identifying fine-scale temperature variability in streams, such as thermal refuges, cold-water inputs from groundwater or tributaries, and localized warming caused by reduced riparian shading or human activities. It can also provide access to remote or difficult-to-reach stream reaches.

SUMMARY OF METHOD

There are four main steps involved with temperature monitoring using RPASs:

1. **Site selection and planning:** Select stream reach based on study objectives. Plan the flight path, considering stream width, riparian vegetation, terrain, and regulatory requirements.
2. **Calibration:** Calibrate the thermal sensor before and after flights. Deploy in-stream temperature loggers or handheld thermometers at select locations for validating RPAS-derived surface temperatures.
3. **Data acquisition:** Fly the RPAS at a low, consistent altitude to maximize spatial resolution while maintaining safe clearance from vegetation. Capture overlapping thermal images along the stream corridor, ensuring stable flight speed and nadir camera position (downward-facing).
4. **Data processing:** Process thermal images using photogrammetry and thermal analysis software to create georeferenced thermal mosaics. Apply corrections for water emissivity and atmospheric effects. Compare RPAS-derived temperatures with in-stream measurements to assess accuracy and correct for sensor drift.

Photo credit: Eric Saczuk

IMPORTANT CONSIDERATIONS

It is important to use a high-quality radiometric TIR sensor (e.g., 640 x 480 spatial resolution) and ensure proper calibration. Accurate temperature measurements depend heavily on sensor sensitivity and regular validation with in-stream temperature measurements at the time of image capture.

Conduct flights during early morning or late afternoon (preferred for maximizing temperature contrast and identifying cold-water inputs), or under overcast skies. Surface turbulence, reflections, and varying atmospheric interference (e.g., water vapor, solar heating) can affect accuracy.

Dense canopy cover and overhanging vegetation can block or distort thermal readings. Flight planning must account for stream accessibility and clear line-of-sight to the water surface. Optional RGB cameras can be used alongside TIR sensors for visual reference and stream boundary identification.

RPASs measure only surface water temperature, which can be problematic for pools that stratify. Understanding this limitation and integrating RPAS data with ground-based measurements may be important for accurate interpretation of stream thermal conditions.

STREAM CHARACTERISTICS

- Extensive sun reflection or partial shading on water surface can be problematic
- May not be suitable for streams with heavy overhead vegetation cover
- High turbulence may decrease accuracy

MEASUREMENT CHARACTERISTICS

- Manual data acquisition (operating RPAS)
- Distributed measurement across stream and along stream network
- Captures water surface temperature only
- Sensor accuracy typically ±0.5°C

SITE ACCESSIBILITY FACTORS

- Suitable for remote foot access
- Can avoid entering stream
- Initial set up involves small equipment (e.g., in-stream temperature measurement for calibration)
- Ongoing monitoring involves small or medium-sized equipment (e.g., RPAS)

SCALE OF EFFORT: INITIAL SET UP

Equipment cost: very low (rental) or moderate (purchase)

SCALE OF EFFORT: ONGOING MONITORING

Equipment cost: very low (rental) or negligible (pre-purchase)
Field time: moderate; ~0.5 day
Field expertise: high; complex hardware and software
Analysis time: moderate; ~1 day
Analysis expertise: high; complex software

PRODUCTS TO CONSIDER

RPAS: DJI Mavic 3T or 4T, Matrice M30T, Matrice M350 with H20T sensor, Matrice M400 with H30T sensor

Software: ThermoConverter for thermal image calibration and standardization; Agisoft Metashape Pro or Pix4DCapture for processing images into radiometric thermal orthomosaics.

ADDITIONAL RESOURCES

Dugdale et al., 2022
Karris-Allen & Kuryluk, 2021
Kelly et al., 2019
Kuhn et al., 2021
Tan, 2016
Torgersen et al., 2001
Vatland et al., 2015