At Biomark we recognize that data is expensive, rarely perfect, and often unavailable for locations and populations of interest; nonetheless, decisions must be made. The **Applied Biological Services (ABS)** team takes precedence in:

- Developing and applying modeling approaches that extend inference with quantitative measures of uncertainty/confidence
- Combining imperfect data sources and/or estimators to reduce bias and uncertainty
- Implementing modelling approaches to support finer spatiotemporal estimators from coarse data
- Capitalizing on sampling opportunities with cost-effective, multidisciplinary data collection to extend inference
- Developing static and interactive data products that deliver answers to management questions in a coherent and unambiguous manner
- Refining automated data collection and processing tools
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Biomark Applied Biological Services (ABS) specializes in applied science, increasing efficiency at each step of the scientific method.

We leverage a team of diverse research backgrounds to design studies that:
- capitalize on sampling opportunities for extended inference,
- utilize statistical approaches with quantitative measures of uncertainty, combine imperfect data sources to reduce bias, and
- produce static and interactive data visualization products that directly inform management decisions.

We take an integrative approach at the study design step to deliver high quality data, analytics, and visualizations designed to eliminate costs while maintaining the broadest application.

The Biomark team has over 150 years of combined experience to help maximize the success and application of studies at any scale.
FIELD SAMPLING

ECONOMICAL TECHNIQUES THAT MAINTAIN STATISTICAL ROBUSTNESS

Quality data are the foundation of accurate, reliable research. Biomark researchers have the statistical and field experience to design and execute sampling opportunities that maximize efficiency and inference. The ABS team has played an integral role in developing and implementing fish and habitat monitoring programs throughout the Columbia River Basin.

Sampling Services Include:

Animal Capture — equipment and training with a variety of capture techniques including electrofishing, angling, seine netting, rotary screw trap operation and snorkel surveys

Animal Handling — experience minimizing stress and injury while handling a variety of species and during tagging (PIT, radio, acoustic, satellite), lavage, and blood and tissue sampling

On-the-ground Surveys — in depth habitat data collection in a variety of terrestrial, aquatic, and mixed ecosystems using customizable electronic data collection applications

Remote Sensing — a variety of drone survey options (hi-res RGB, multispectral) and products (orthomosaic, dense cloud, digital elevation model), in addition to the integration and analysis of other remotely sensed data such as LiDAR and satellite imagery
A supervised random forest pixel-based classifier was developed to automate the quantification of woody debris in drone imagery. This technique is also used to classify bare earth, water, and vegetation, saving researchers hours of manual image processing.

ABS has also developed an object-based classifier such as this regional convolutional neural network (rCNN) model that identifies and tracks animals commonly sighted along the south east Florida coast, like the manta ray pictured.
Ecological datasets are often noisy and may contain extraneous information. Biomark data scientists have developed a number of pipelines that transform raw data into meaningful observations. These tools save researchers days of manual data processing and reduce error.

Data Processing Services Include:

* **PITcleanr** — an R package to clean large PIT tag observational datasets and to determine the migration route of thousands of individuals from hundreds of thousands of observations

* **telemetyr** — an R package to clean noisy radio telemetry detections from an array of receivers and into capture histories for movement modeling

**Multisource Data Pairing** — tools to temporally and spatially join various data sources such as fish observations, on-the-ground habitat data, drone imagery, and satellite data

**Automated Imagery Processing** — employ machine learning techniques to automate data extraction from drone and satellite imagery

Open source packages available on GitHub!
Communicating data driven results in an appropriate, explicit manner is a critical step in the scientific process. ABS staff are skilled in a variety of static and dynamic communication platforms with tools to design, implement, and deliver actionable results to a variety of audiences.

**Scientific Communication Services include:**

**Data Visualization** — deliver clear results tailored to the audience using a suite of visual tools including static figures that display quantitative evaluations with qualitative context, dynamic visualizations that capture animal movement through space and time, and imagery products such as 3D renderings and virtual site fly throughs

**Interactive Web (Shiny) Apps** — a dynamic application for visualizing a variety of data sources in the appropriate context, such as changes across space, time, and population

**Workshops** — custom workshops for a variety of groups including conference organizers, universities, and private groups. Previous workshops include PIT tagging and data collection, instream antennas and remote site installation and maintenance, and big data analyses for movement and abundance, and study design and implementation for wildlife management
ABS includes certified drone pilots with experience surveying environmentally complex remote sites. Drone imagery products include orthomosaics, 3D renderings, site fly-throughs, and dense clouds (pictured).

Biomark staff frequently work with a variety of groups to host customized training workshops such as this PIT tagging training in Santa Fiora, Italy.
ABS developed a password protected Shiny app to estimate the abundance of natural and hatchery origin fish using PIT tag technology. Stakeholders can access these estimates in real time to better direct fisheries management.
Precise and unbiased estimates of abundance are confounded by dynamic ecosystems with spatiotemporal changes, as well as to commonly violated statistical assumptions. ABS biometricians specialize in developing analytical tools that combine multiple imperfect estimators to produce population level abundance estimates with measured uncertainty. The incorporation of other techniques such as dendritic network analyses leverage transition probabilities to estimate abundance through complex, branching environments.

Abundance Modeling Services Include:

Mark-Recapture Modeling — estimate total population size using multiple sample events to determine marked to unmarked ratio and extrapolate to the population level

State Space Modeling — a modeling approach robust to changes in survey type and effort (common among long term monitoring programs) that maximizes data from multiple sources to produce abundance estimates with refined measures of uncertainty

Branching Patch Occupancy Modeling — leverage a network of recapture infrastructure (e.g., instream PIT tag detection systems, acoustic receivers) to estimate movement and detection probabilities of animals throughout a branching network
Fish-Habitat datasets often incorporate nonlinear relationships, correlated variables, and substantial noise; all of which make establishing the relationship between species and their habitat challenging. ABS researchers have developed advanced analytical tools that pair fish abundance and habitat characteristics to define these elusive relationships.

Fish Habitat Modeling Services Include:

**Habitat Suitability (HSI)** — leverage existing habitat suitability curves to determine depth, velocity, temperature, and composite suitability by species and life stage

**Habitat Preference** — investigate high-density sites to evaluate preferred habitat characteristics by species and life stage to direct restoration efforts

**Quantile Random Forest (QRF) Habitat Capacity** — evaluate habitat capacity using random forest methods that capture non-linear fish-habitat relationships, naturally incorporate interactions between habitat characteristics, and are robust to outlier data points

**Bioenergetics** — assess impacts of morphological simplification and water management using bathymetric LiDAR, spatially continuous numerical models, and stream characteristics
QRF habitat capacity estimates overlaid on high-resolution drone imagery provide quantitative analyses in a qualitative context. ABS researchers work to develop economical tools and analyses with broad statistical and functional applications.
ABS specializes in telemetry study design to optimize sampling opportunities. We employ a number of techniques including fixed and mobile (pictured) detection of a variety of tagging technology to investigate animal movement and behavior.
MOVEMENT & SURVIVAL
LEVERAGING TELEMETRY TO TRACK AND OBSERVE WILD ANIMAL BEHAVIOR

Telemetry provides researchers an unbiased window into animal movement behavior in their natural habitat, especially for cryptic and remote species. Our team of in-house biometricians, data scientists, and telemetry experts have over 65 years of combined experience in tracking, analyzing, and predicting animal behavior.

Movement & Survival Services Include:

**Study Design and Implementation** — develop study designs based on project goals and existing infrastructure to deploy antennas/receivers, evaluate range, customize tag reporting, and minimize stress during animal capture, tagging (surgical or external), and release

**Data Collection** — using various telemetry technology including fixed and mobile detection of PIT, acoustic, radio, satellite & accelerometer tags to make inferences about animal movement, behavior, and survival

**Data Processing (telemetyr and PITcleanr)** — open source R packages to clean detections from radio receivers or PIT tag detection systems into capture histories for movement modeling

**Analysis and Visualization** — infer movement, survival, and behavior with techniques such as Cormack-Jolly Seber (CJS) and Hidden Markov (HMM) modeling, and display results in a clear manner through static and dynamic visualizations
Life Cycle Models are a mainstay of applied ecology, conservation biology, and fisheries management. Ad hoc approaches can lead to biased inference about key processes such as the strength of density dependence and the magnitude of environmental variability in recruitment. ABS researchers are on the cutting edge of statistical advances that facilitate a more rigorous, unified approach to fitting life cycle models by combining all relevant data in a state-space framework.

Life cycle modeling services include:

Integrated Population Modeling — combine multiple data sources of various scales (individual, evolutionary significant unit (ESU), population level) within a Bayesian framework to leverage any available data

salmonIPM — an open source R package built on the Stan platform for Bayesian inference via Hamiltonian Monte Carlo, a state-of-the-art tool that can handle complex high-dimensional models

Advantages of IPMs

- Account for variation through space, time, and across populations to reduce bias in estimates of population viability
- Robust to fluctuations in data by borrowing strength from data-rich years to improve estimates in data-poor years
In contrast to traditional spawner-recruit regression based on brood-table run reconstruction, IPMs are fitted to “raw” data and distinguish between process error (the true but unknown fluctuations in the population dynamics) and observation noise (our imperfect measurements of the population). The result is less biased short-term abundance forecasts and long-range projections of population viability.
Genetic tools for conservation and management provide a platform to track individuals, mass mark populations, track migratory pathways, evaluate stock structure and diversity, investigate mixed populations, and monitor population abundance or effective population size. ABS biometricians and geneticists have extensive experience incorporating genetic data into management programs, specifically with complex populations including fish born in both natural and hatchery environments.

Applied genetic services include:

**Parentage Based Tagging (PBT)** — a non-invasive method to tag thousands or millions of offspring simply by genotyping the parental broodstock that allows for tracking of individuals while eliminating traditional physical tagging considerations such as tag loss, detection issues, and handling stress.

**Genetic Stock Identification** — identify the origin of individuals or mixed populations by comparing the genotypes of individuals to a baseline characterizing all potential contributing populations, commonly used for assessments of stock structure or abundance.

**Population Genetics** — monitor the genetic structure and diversity among populations, effective population size and demographics, and assessments of selection and adaptation.
PUBLICATIONS & CODE

Estimating Abundance

Movement & Survival

Genetics
Fish-Habitat Modeling

Life Cycle Modeling

Imagery Analytics

Public Repositories:
PITcleanr - github.com/BiomarkABS/PITcleanr
telemetyr - github.com/BiomarkABS/telemetyr
Life cycle modeling- github.com/ebuhle

For a full list of staff and publications please visit www.biomark.com