SYMPOSIUM

Fishery Assessment Using Remote Sensing Technologies

1:20 pm – 5:00 pm (Monday August 24th)

Room: Sheraton Grand Ballroom

Organized by Fritz Funk and Brian Nakashima

Moderated by Fritz Funk and Brian Nakashima

1:20 [131] An Evaluation of the Potential Use of Airborne Lidar for Inventorying Epipelagic Fish Schools
John R. Hunter* and James H. Churnside

1:40 [132] Using an Airborne Imaging Spectrometer to Detect and Assess Inshore Schools of Pre-Spawning Pacific Herring (*Clupea pallasi*)
Fritz Funk* and Gary A. Borstad

2:00 [133] The Potential Role of Spaceborne Synthetic Aperture Radar Observations in Fisheries Management
P.Clemente-Colón*, W. Pichel and K.Friedman

2:20 [134] Testing the Feasibility of Using an Underwater Laser Line Scanning System for Marine Fishery and Habitat Assessment
Robert S. Otto*

2:40 [135] Modeling Properties of Airborne Lidar Surveys for Epipelagic Fish
Nancy C.H. Lo*, John R. Hunter and James H. Churnside

3:00 BREAK

3:20 [136] Assessing Capelin (*Mallotus villosus*) Stocks Using Data from Aerial Surveys
Brian S. Nakashima* and Gary A. Borstad

3:40 [137] Recent Investigations with Airborne Lidars for Fish Detection and Assessment
Charles W. Oliver* and Elizabeth Edwards

4:00 [138] Progress in the Development of Aerial Surveys and Direct Photographic Assessment of N. Atlantic Bluefin Tuna
Molly E. Lutcavage* and Jennifer Goldstein

4:20 [139] Calibrating and Improving the Utility of Aerial Surveys via the Use of CASI, Videography, and Acoustics
E. D. Brown*, G.A. Borstad, Kevin D. E. Stokesbury and B.L. Norcross

[131] An Evaluation of the Potential Use of Airborne Lidar for Inventorying Epipelagic Fish Schools

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In its most basic form, a lidar produces short pluses of laser light which pass through the water surface and reflect off fish and particles in the water. A receiver waits for the returning reflected pulse; the strength of the returning pulse separates fish targets from the reflectance of small particles, and the elapsed time indicates the range (depth below the surface) of the target. A lidar survey system for fisheries is being developed by NOAA. Work to date includes testing radiometric lidar at sea, aquarium calibration of fish reflectivity, and modeling of survey performance. Schools of sardine and anchovy were detected down to depths of 30-40 meters and mean target strength and intersected school volume were measured, but neither fish size nor species could be identified from lidar images. Thus, an index of school biomass is practical but species identification will require other sensors. Night may be the preferable time for lidar surveys because at night fish are closer to the surface and the system gain can be increased thereby increasing lidar sensitivity. Algorithms for automatic counting schools and measuring their relative biomass are needed before airborne lidar can be routinely used for fishery surveys.

[132] Using an Airborne Imaging Spectrometer to Detect and Assess Inshore Schools of Pre-Spawning Pacific Herring (*Clupea pallasi*)

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While multispectral digital imagery is commonly used to assess and classify coastal marine habitats, we used a push-broom spectrographic imager to assess fish directly. We acquired spectral signatures of herring schools and adjacent shallow habitats and determined that multispectral frequency bands could easily discriminate nearshore herring schools from background habitat much better than existing aerial observations. In addition, the digitally enumerated surface areas removed the subjectivity of human observers. Although the spatial resolution of satellite multispectral images approaches that of the important large herring schools, we used an airborne instrument to fly under the frequent cloud cover which would often preclude acquiring satellite imagery during the brief inshore spawning period. The digital images allow us to examine and classify school shapes, which could resolve overlaps in run-timing that are a problem with the current aerial survey estimator. Wide, shallow depth profiles adjacent to many herring spawning areas constrain school depth variability and keep the upper layer of the schools visible. However, variable packing density remains a problem. We generalize our findings to contend that species color adapted to a pelagic environment should be detectable in the green band if part of their life history brings them into shallow nearshore waters.

[133] The Potential Role of Spaceborne Synthetic Aperture Radar Observations in Fisheries Management

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Spaceborne Synthetic Aperture Radar (SAR) images can be used to locate ships day and night and under practically all-weather conditions. Ships are in general good radar hard targets since they tend to have large radar cross sections. They act as efficient corner reflectors returning a large portion of the incident microwave energy and allowing for easy detection under appropriate sea surface background clutter conditions. The ability to image these hard targets can be exploited to monitor and manage the operation of fishing fleets in sensitive or regulated area. SAR images are also very sensitive to the presence of organic substances on the water surface. These materials tend to dampen the small gravity and capillary waves that the SAR responds to. Dampening of these so-called Bragg waves results in very low backscatter and allows for the SAR imaging of slick features formed by these substances under appropriate wind conditions. Regions of high biological activity are often characterized by the presence of such natural slicks. Additional slick patterns closely associated with the presence fishing vessels are now being documented. These patterns are suspected to be the result of by-catch or fish processing residue dumped into the open water as a normal part of fishing operations. Fishing related slicks can be sufficiently distinct from natural slick patterns as to allow for easy detection through a cursory look of the SAR imagery. The location, pattern, and persistence of these features may be useful in extracting information about active (at the time of the SAR observation) or previous (before the time of the SAR observation) fishing activities in a monitoring region.

[134] Testing the Feasibility of Using an Underwater Laser Line Scanning System for Marine Fishery and Habitat Assessment

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The Alaska Fishery Science Center's Kodiak Laboratory, in cooperation with the Alaska Department of Fish and Game, conducted a feasibility study of using an underwater laser line scanning system (LLSS) to detect trawl-induced physical and biological changes in bottom habitat. Operations consisted of: 1) general observations of organisms, bottom features and targets such as derelict crab pots (20 tows), 2) targeted tows where sonic-tagged pods of king crabs were observed (5 tows) and 3) observation of 6 separate fresh trawl tracks (8 tows). Images obtained are similar to black and white television pictures and available in still frame or video format. Of 33 tows, the LLSS produced usable images for the entire track in 17 cases, usable images for part of the track in 14 cases and failed to obtain images in 2 cases. Web in lost crab pots, numerous organisms (starfish, crabs, flounders, kelp) and bottom features (rocks, shells, lost line, bottles, cans) were routinely and clearly visible. Observations of trawl tracks were well imaged and repeatable for two tracks, partially observable for two tracks and failed for two tracks. Trawl tracks were difficult or impossible to observe in well sorted sand mixed with shell hash, more easily observed in sand/silt-mud bottom and clearly observable in soft bottom. The LLSS fills a gap between side-scanning sonar and ROVs, is easily deployed and capable of observing some effects of trawling. The LLSS has considerable potential as a resource assessment tool for macro-invertebrates such as crabs or scallops.

[135] Modeling Properties of Airborne Lidar Surveys for Epipelagic Fish

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We model a Lidar survey with the objective of evaluating possible tradeoffs in instrument design affecting survey precision and accuracy. Two classes of tradeoffs are considered swath width, and depth specific detection of fish schools for fish length of 10-34 cm and packing densities of 0.53-115/m^3. The effect of swath width was minimal. Only when the diameters of fish schools are small and population level is less aggregated does the swath width affect the probability of encountering fish schools. For the NOAA lidar (laser power of 67 mJ), with an attenuation coefficient of 0.1, the model indicates that 64% of anchovy schools can be detected. The effect of packing density on the probability of detection is greater for fish near the surface water (<20 m) than for fish in the deeper water (>30 m). The effect of packing density decreases with the decrease of attenuation coefficient. Owing to the rapid attenuation of light with depth, a ten fold increase of the laser power would only increase the maximum penetration depth by 10 m in coastal water. Such an increase in penetration depth would have negligible effect on the probability of detection due to the skewed vertical distribution of fish schools.

[136] Assessing Capelin (*Mallotus villosus*) Stocks Using Data from Aerial Surveys

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Mature capelin aggregate in schools in shallow water in the spring prior to spawning on gravel beaches along the coast of Newfoundland. This behaviour underlies the basis of an aerial survey program which has been evolving since 1982. The surveys began with aerial photography in 1981, upgraded to an imaging spectrometer (CASI) in 1991, and experimented with video imagery in 1997. The photographic method was limited to sunny conditions with light winds. Digital imagery expanded data collection to overcast conditions and facilitated data analysis. Video recording appears to improve school detection and is cost-effective. Aerial surveys of the coastline are designed to collect information on the distribution and surface area of capelin schools as they aggregate in nearshore waters during the spawning season. The distribution of these schools corresponds to availability of capelin in nearby fixed-gear fisheries. The relative abundance index is based on the highest estimate of total area of all schools observed along each transect. Peak estimates are timed to periods of high egg deposition and intense spawning activity. The index assumes that the surface area of capelin schools is proportional to relative abundance. Recent results from joint aerial/acoustic experiments suggest that during spawning the surface area of schools and their acoustic densities are related. Trends in relative abundance from aerial surveys and other indices are used to develop a standardized index of abundance and of year-class strength.

[137] Recent Investigations with Airborne Lidars for Fish Detection and Assessment

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Airborne lidars have potential application in commercial fisheries (detection, bycatch reduction), fisheries assessment and protected species management (detection, relative abundance, surveys), and environmental monitoring. Locating sub-surface fish with lidar is a technology which could be used 1) during either the day or at night to detect fish schools deeper than current visual methods allow, 2) to detect schools missed because of environmental and human factors (e.g., whitecaps, glare, fatigue, distraction), and 3) may be useful for species identification as well. The airborne platform (helicopter or fixed-wing) results in greater coverage relative to ships. A fish-finding lidar is expected to be able to detect fish schools at depths 3-6 times greater than the unaided human eye (e.g., 30-60 meters). The Dolphin-Safe Research Program is investigating five airborne lidars: 1) the NMFS- developed lidar (Osprey), 2) the Kaman Aerospace (Tucson, AZ) Corporation's imaging lidar (FISHEYE), 3) the NOAA Environmental Technology Laboratory's (Boulder, CO) Experimental Oceanographic Fisheries Lidar (FLOE), 4) the Arete Associates (Tucson, AZ) 3D Streak-Tube Imaging Lidar (STIL), and 5) the Detection Limited (Laramie, WY) lidar. Four systems have been flown and the last is under design. These lidars include radiometric, 2D imaging, and 2D imaging applications. Studies include development, capabilities, and potential impacts to marine animals.

[138] Progress in the Development of Aerial Surveys and Direct Photographic Assessment of N. Atlantic Bluefin Tuna

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Since 1993, we have conducted fishery-dependent aerial surveys in collaboration with commercial spotter pilots to assess the relative abundance, distribution, schooling behavior, and environmental associations of giant bluefin tuna (Thunnus thynnus) in the New England region. Spotter aircraft carry a data acquisition system to record search tracks and school locations. Pilots photographed schools, allowing enumeration of the number of individuals in the surface layers. Surveys (1994-96) documented from 479-794 geo-referenced schools/yr, with cumulative totals ranging from 41,001-47,810 bluefin counted annually. Spotter pilot search effort ranged from 52,828 - 82,666 nmi of trackline. Highest daily surface counts ranged from 8,514-13,857 bluefin tuna. The lack of information on total school biomass, the percentage of schools occurring below the surface and fish size pose problems for aerial surveys. We have addressed some of these problems in a hydroacoustic tracking study of bluefin tuna to determine swimming speeds and surfacing behavior. In 1998 we will examine the feasibility of using LIDAR to determine total biomass of schools and fish size. In the context of stock assessment and fishery management concerns, our long-range goal is to develop a fishery-independent, regional index of abundance for spawning size classes of bluefin tuna.

[139] Calibrating and Improving the Utility of Aerial Surveys via the Use of CASI, Videography, and Acoustics

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Since 1995, broadscale aerial survey methodology has been developed and used to measure the distribution and relative abundance of schooling forage fishes in Prince William Sound Alaska. The aerial database includes locations, numbers and relative sizes (surface area) of schools, as well as overlap with flocks of foraging seabirds, marine mammals and locations of jellyfish aggregations. In order to understand the accuracy and precision of the data from the surveys, several measures were taken: 1) double counted surveys were conducted, 2) repeat surveys over various time scales were flown, 3) a number of aerially sighted schools were captured in nets or on video for validation, and 4) the results in a given area were compared to independent measurement techniques. The independent techniques included acoustic surveys of defined regions and the collection of spectrographic imagery along transects via the use of a Compact Airborne Spectrographic Imager (CASI). Visual counts of numbers of schools and estimations of school surface areas were compared with the CASI counts providing a measure of bias and precision presented here. Age- and species-specific acoustic distributions and catches were compared with the visual aerial survey results to improve the interpretation of the data and to provide estimates of density allowing aerial survey results to be used to estimate biomass. Examples are presented here. Finally the sources of bias and error within the survey are identified and compared to the variability of the data itself on horizontal and temporal times scales. We conclude that the total error due to surveyor bias, surveyor precision, survey condition, temporal variability on the scale of less than a week is significantly less than the natural variability within the data itself and within the range acceptable for fishery managers. The techniques described in this paper produce reasonably precise, accurate and repeatable results.