

Theme Session P

New methodology for tracking fish, mammal, and seabird behaviour and migrations

ICES CM 2008/P:01

Seasonal migrations of rock sole (*Lepidopsetta polyxystra*) in the eastern Bering Sea using the Tidal Location Method on archival tag data

David Somerton and Dan Nichol

Historical mark–recovery studies have indicated that rock sole can have seasonal migrations of several hundred kilometres between summer feeding areas and winter spawning areas, but the details of these migrations are poorly known because of the inconsistent recovery pattern of the commercial fishery. In this paper we examine seasonal migration from the perspective of entire individual migration trajectories, rather than simply the endpoints, using archival tag data from two rock sole recovered after more than 10 months at liberty. Three-day segments of the hourly depth data were compared with depths predicted by a tide simulation model of the eastern Bering Sea over a grid of potential fish locations. Maximum likelihood was used to determine the best grid location at each time segment, taking into consideration not only the similarity in the tide height variation and mean depth within each grid cell but also the likelihood of reaching each cell given an assumed swimming speed and distance from the last determined position. Most probable tracklines were then constructed by joining the best grid locations at each time interval using a form of cubic spline smoothing, in which the spline stiffness is varied until the error about the smooth is the same as the error associated with repeatedly positioning a pressure sensor on an oceanographic mooring with a known location. The resulting trajectories indicate that migrations are episodic, with periods of little motion punctuated by periods of rapid, directed motion.

Keywords: fish migration, archival tags, tidal location method, rock sole.

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ICES CM 2008/P:02

Gampath: a method for smoothing noisy telemetry data

Mike Lonergan, Mike Fedak, and Bernie McConnell

System ARGOS is widely used to track marine mammals. Satellites measure the Doppler shift in signals from low-powered transmitters attached to animals and use this to estimate their locations. The interpretation of these data is complicated by the irregular intervals at which locations are estimated, which require a suitable satellite being overhead while the tag is at the surface, and the large and non-Gaussian errors in the estimates. We demonstrate software for extracting animal tracks from these data that provides a way to utilize location information of all qualities and estimate animal locations between observations. Code to fit the paths is available in Gampath, an R library. Within this, animals' paths in the north–south and east–west directions are represented with separate cubic splines, removing the requirement to assume that animals turn corners at either fixed times or when location estimates are made. The splines are fitted by penalized regression with a common quadratic penalty (smoothing parameter), and parameters for *t*-distributions, describing the fat-tailed locational errors for each ARGOS quality class estimated with the R library GAMLSS. The method is applied to data from hybrid GPS/ARGOS tags attached to two grey seals (*Halichoerus grypus*) at Abertay Sands on the east coast of Scotland. These operated for 131 and 152 days, producing 1741 and 1040 ARGOS locations respectively. The smoothed tracks are compared with 731 and 590 GPS locations, and estimate 95% of the locations to within 9.5 km and 22 km. (The equivalent values for a speed filter are 15 and 30 km.)

Keywords: path smoothing, generalized additive models.

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ICES CM 2008/P:03

Sex-specific seasonal foraging tactics in adult grey seals (*Halichoerus grypus*) are revealed by behaviour discriminating state-space models

Greg A. Breed, Ian D. Jonsen, Ransom A. Myers, W. Don Bowen, and Marty L. Leonard

Identifying where and how animals forage is key to understanding their ecology and ecosystem role. In many large pelagic animals, observing behaviour is limited almost exclusively to telemetry studies. Discriminating different behaviours from tracking data has been a key, but often elusive, goal. Here we use state–space models (SSMs) to fit a correlated random walk model that switches between two unobserved behavioural states (nominally foraging and travelling) to 84 (41 male and 43 female) adult grey seal (*Halichoerus grypus*) satellite telemetry tracks. We demonstrate the method's ability to estimate locations from error-prone satellite observations and classify behavioural state by comparing against time–depth recorder data and bathymetry. The SSM results reveal markedly different spatial behaviour between the sexes, fitting well with sexual size dimorphism and known dietary differences, suggesting that males and females deal with seasonal prey availability and reproductive costs differently. From these results we are also able to produce behaviourally informed habitat-use maps, showing a complex and dynamic network of small, intensely used foraging areas. Our flexible SSM approach clearly demonstrates sex-related behavioural differences, fine-scale spatial and temporal foraging patterns, and a clearer picture of grey seal ecology and role in the Scotian Shelf ecosystem.

Keywords: animal movement, foraging, correlated random walk, switching model, seal.

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ICES CM 2008/P:04

Spatial dynamics of Atlantic cod (*Gadus morhua*) in the North Sea: results from a large-scale electronic tagging programme

David Righton, Francis Neat, Victoria Quayle, Peter Wright, Martin Pedersen, Mike Armstrong, Victoria Hobson, and Henrik Svedang

Electronic tags have revolutionized research into the behaviour of marine fish. With appropriate analytical tools they can provide insights into movements, habitat occupation, and environmental preferences. Here, we report on the results of a large-scale programme of electronic tagging of Atlantic cod in the North Sea, spanning the years 1999 to 2008. More than 1000 cod of 37–110 cm were tagged, and over 300 of the tags have been returned, yielding data covering over 40 000 days of data. We applied a range of different geolocation techniques to infer the daily locations of each cod, from which the scale and rate of movements were estimated. We use these data to describe fundamental features of cod ecology, such as the balance between homing and resident behaviour, the location of feeding and spawning grounds (and the migratory pathways between them), and the seasonality of migration and its impact upon substock structure. The results provide a major step forward in our understanding of how Atlantic cod exploit and utilize their environment, and have wide-ranging implications for our expectations of how cod stocks may respond to changes in the environment and fishing.

Keywords: Atlantic cod, electronic tag, geolocation, behaviour, migration.

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ICES CM 2008/P:05

Increasing confidence in tidal-based geolocation models by including temperature information: the case of cod in the northern North Sea

Barbara Berx, Francis Neat, Martin Wæver Pedersen, Peter Wright, and Roger Proctor

The Atlantic cod (*Gadus morhua*) is an important species of the North Sea commercial fishery, although its numbers have shown a significant decline in recent decades. The possibility of distinct populations within the species, based on patterns in migration and breeding behaviour, has highlighted the need for a more regional approach to marine and fishery management. The development of data storage tags (DSTs) which record ambient environmental conditions, such as temperature, light, salinity, and depth, has greatly advanced our understanding of fish movements in response to their environment. Key to this is the ability to geolocate individuals from the data recorded. Tidal geolocation relates observed pressure changes to those expected from tidal modelling, creating a range of possible locations centred on areas where these match. However, the accuracy of tidal-based geolocation varies considerably depending on the proximity to amphidromic nodes, and for some regions it is difficult to implement. Nevertheless, this method can be improved by including information from the temperature measurements because this will narrow down the number of possible areas. A recently developed near-bed temperature distribution for the northwest European continental shelf has made it possible to include temperature in an existing geolocation toolbox. The methodology of creating temperature fields and combining these with tidal information for geolocation is presented and illustrated with some examples of DST records from cod at liberty in the northern sector of the North Sea.

Keywords: cod, geolocation, tides, temperature.

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ICES CM 2008/P:06**Behavioural plasticity of migrating juvenile southern bluefin tuna in relation to oceanography of the south Indian Ocean**

Sophie Bestley, John Gunn, and Mark Hindell

The selection of different oceanic environments by highly migratory pelagic predators, and their behaviour within those different habitats, is now observable with electronic tagging technologies. We use data obtained from archival tags implanted in juvenile southern bluefin tuna (*Thunnus maccoyii*) to (i) characterize the oceanographic habitats used throughout an annual migration cycle on the basis of water column structure (i.e. temperature-at-depth data), and (ii) test whether and how the vertical behaviour patterns of southern bluefin tuna altered between different habitat types and other factors. In the south Indian Ocean, juvenile southern bluefin tuna occupied eight major habitats between the southern margin of the subtropical gyre and the northern edge of the Subantarctic Front. Although a high degree of variability in behaviour was evident both within fish and between fish, mixed-effect models identified consistent behavioural responses to habitat, lunar phase, migration status, and diel period, indicating that vertical movements are predictable among individuals. Our results indicate that southern bluefin tuna do not act to maintain preferred depth or temperature ranges, but in fact show highly plastic behaviours in response to their changing ocean environment. This is consistent with the description of southern bluefin tuna as a highly opportunistic predator, capable of exploiting a variety of ecological niches throughout subtropical to subantarctic waters. Such behavioural plasticity provides significant challenges for the traditional interpretation of fishery data used in stock assessments.

Keywords: southern bluefin tuna, archival tags, south Indian Ocean, seasonal migrations, habitat characterization, pelagic habitat use.

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ICES CM 2008/P:07**Individual migratory schedules and wintering areas of the largest North Atlantic seabird, the northern gannet**

Stefan Garthe and Robert W. Furness

Seabirds are highly mobile top predators in marine ecosystems. The highest numbers of seabirds occur near breeding colonies, at migratory bottlenecks and also in winter areas. Knowledge of migration corridors and wintering areas, however, is substantially limited as standard methods such as censuses by ship and aircraft cannot cover large enough areas, and do not address the behaviour of individuals. Classic tools such as band recoveries do not reveal much, as pelagic species spend almost their entire life at sea. We studied migratory schedules and winter areas of northern gannets (*Morus bassanus*), the largest seabird in the North Atlantic, breeding on Bass Rock, UK, by geolocation. Breeding adults were equipped in two consecutive winters with small light and temperature loggers (from Earth and Ocean Technology, Kiel, Germany) that were retrieved the following breeding season. Some gannets stayed in winter in the North Sea but most birds travelled to areas further south, with a hotspot off West Africa. A few birds moved into the Mediterranean Sea. Direct distances between Bass Rock and the core winter area ranged from 170 to 4552 km (winter means: 2154 km and 2897 km). Gannets followed the continental shelf quite closely while migrating. High proportions of gannets stayed in areas where demersal fisheries produce high rates of discards, which gannets may utilize. The winter areas also overlapped with areas of high pelagic fish catches. Costs and benefits for gannets staying in winter in the North Sea are compared with those of gannets wintering off West Africa by contrasting flight costs, phenology, sea surface temperature, and food availability.

Keywords: seabird, migration, winter area, discards, geolocation.

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ICES CM 2008/P:08**Recent advances in marine mammal tracking**

Bernie McConnell and Mike Fedak

The field of marine mammal telemetry has evolved rapidly in the last 15 years, extending our ability beyond simply tracking their geographical movements. We can now integrate their movements and behaviour with their immediate physical and biological environment. Oceanographic sensors for temperature, salinity, and chlorophyll make it possible to relate the animals' diving behaviour to water mass characteristics. Marine mammals are now providing a large fraction of the oceanographic data in Polar Regions and other logistically difficult parts of the ocean. Remote sensing and models provide synoptic environmental data from which the animal's preference can be determined. On-board cameras can provide images of the immediate prey fields and on-board hydrophones can detect the ambient noise as well as vocalizations generated by the animals themselves. A future generation of marine mammal tags could be equipped with acoustic sensors to detect the presence of tagged fish under the Ocean Tracking Network. The condition of an animal, as represented by its buoyancy, can be determined by estimating, either *post hoc* or onboard, changes in the rate of ascent/descent in drift dives. Multi-axis accelerometers can provide information on the energetics of animals and potentially extend what can be learned remotely about changes in the animals' mass and condition. New techniques to relay data ashore are being developed and used. These include iridium, GSM (mobile phone), and data sharing between animals. The advent of rapid GPS fixes (0.2 s from cold start) using the Fastloc system permits the fine-scale ecology to be investigated.

Keywords: seal, marine mammal, tracking, Argos, GSM GPS.

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ICES CM 2008/P:09

Geolocation of Icelandic cod from DST data using a particle filter method with attractor function

David Brickman and Villi Thorsteinnsson

During the last decade, hundreds of adult Icelandic cod have been tagged with data storage tags (DST) providing temperature and depth time-series of the fishes' movements. In this paper we use a particle filter (PF) method to determine the most probable path of the fish through the water column. Simulated fish (particles) evolve in monthly temperature fields derived from a high-resolution numerical circulation model of Iceland waters. The results of investigations such as these—with temperature–depth data only and uncertain model temperature fields—tend to be characterized by high uncertainty and difficulty in simulating the known recapture positions. To overcome these difficulties, the PF model is modified to include a factor that weights the particle position relative to the recapture position. This weight is time-dependent, increasing in importance as the simulation proceeds, thus serving to “attract” particles to the recapture position. Over 25 DST returns are simulated. We find that the attractor function leads to improved model results in almost all cases. We use the combined simulations to look at some simple physiological aspects of cod movement in Icelandic waters.

Keywords: particle filter, Icelandic cod, DST, geolocation.

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ICES CM 2008/P:10

The Ocean Tracking Network: using electronic tagging technology to better understand animal behaviour, ecology, and ocean physics

M. J. S. Stokesbury, R. K. O'Dor, and J. Sheng

Electronic tags provide information on the movement, migration, behaviour, and stock structure of animals. For large, surfacing animals, archival tags store data and relay them to satellites, otherwise the animal must be recaptured for the researchers to recover the data. Acoustic tags send signals to passive receivers when a fish passes within the acoustic range of the receiver. Ecosystem-based management requires a procedure that obtains data from individuals when they interact with members of their population. In addition, ecological interactions with other groups of animals, and relationships between animals and the physical properties of their habitat are needed. New technology will mesh acoustic and archival tags to allow archived data to be transmitted acoustically to passive receivers. This will allow repeated data retrieval without having to recapture the animal. This new technology includes a “business card” (BC), which is a miniaturized receiver coupled with a coded pulse transmitter. These tags will exchange and record individual-specific codes when two tagged objects come within acoustic range of each other, and may be used on animal “bioprobes” or oceanic gliders “roboprobes”. This procedure will provide information on animal interactions and spatial information on animals to complement information obtained from the extensive infrastructure of moored passive acoustic receivers included in the Ocean Tracking Network. Integration of tracking data with coastal

shelf models, such as Dalcoast3, and biophysical sampling will also help us to improve coastal oceanographic models and aid understanding of how animals respond to their changing environment.

Keywords: electronic tags, acoustic tags, archival tags, animal behaviour, ecology.

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ICES CM 2008/P:11

The life history transmitter: spatially explicit detection of mortality and predation in a marine mammal

Markus Horning, Jo-Ann Mellish, Lowell Fritz, Rod Towell, and Roger Hill

We used implanted life history transmitters to monitor mortality and predation in juvenile Steller sea lions in Prince William Sound, Alaska. The tags record sensor data throughout the life of their host, up to a decade, and temperatures outside preset thresholds time stamp mortalities. Transmissions to the ARGOS satellite system commence after extrusion of the positively buoyant tag. Predation results in immediate extrusion and transmission, and rapid temperature fall. Non-acute death should result in gradual declines from whole carcass cooling, and delayed extrusion and transmissions. Initial data returns from three mortalities from nine deployments suggest two predation events and support the viability of this new concept. We compared annual survival rates from our approach with resight-based rates from 255 branded juveniles in the same region. Brand monitoring does not deliver data on causes or locations of mortalities, but can provide movement patterns of individuals while alive, and age class-specific survival rates. Variance and standard error estimates suggest that monitoring of 32 implanted animals over two years could deliver comparable uncertainties in survival rates to 255 branded animals observed over 1–4 years, highlighting the advantage of a technique with spatially and temporally unconstrained resight effort. Life history transmitters provide spatially explicit data on predation and long-term emigration patterns through end-of-life locations. This will contribute to assessments of biomass flow between spatial ecosystem compartments, and across trophic levels.

Keywords: life history transmitter, tracking, survival, emigration, predation, pinniped.

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ICES CM 2008/P:12

Indirect observation of fish movements: a general methodology applied at different scales

Uffe Høgsbro Thygesen, Junita Karlsen, Anders Nielsen, and Martin Wæver Pedersen

When fish movements are observed indirectly through light, depth, or temperature readings, the uncertainty is typically large and advanced statistical analysis is needed to increase accuracy. The most well-established framework for this analysis is the Kalman filter. Recently, we proposed a computer-intensive alternative, which does not require near-Gaussian distributions or near-linear relationships. In this approach, the probability distribution of the fish's position is represented non-parametrically and determined by solving the governing partial differential equation numerically and combining with methods from hidden Markov models. We then demonstrated the method on cod in the North Sea using the tidal method. Here, we discuss the wider applicability of the method to other situations, e.g. to the small-scale tracking of fish tagged with acoustic transmitters within arrays of acoustic receivers. When initiating a new study of fish movements involving new species, geographic regions, or technology, the issue of scale invariably arises: Which spatial and temporal scales can be resolved, and what is the movement of the animal at those scales? To elucidate this issue, we show results from a simplified version of the problem, where the Kalman filter equations can be solved in closed form. From this we derive simple scaling relationships between the motility of the fish and the attainable accuracy of the final estimated path.

Keywords: fish movements, data storage tags, geolocation, Kalman filtering.

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ICES CM 2008/P:13

Advances in light-based positioning in an oceanographic context

François Royer and Philippe Gaspar

Electronic tags have become valuable tools in monitoring and understanding the spatial dynamics of pelagic fish, sea turtles, and marine mammals. Light-based positioning, one of the few techniques allowing for underwater geolocation, has recently benefited from better astronomical models and estimation procedures. Including oceanographic variables (e.g. sea surface temperature) has also been shown to greatly help in this process. In this study we show how three-dimensional information (e.g. from circulation models or profiling floats) can be included to improve estimated locations and to provide a better view of the animal's vertical habitat. We develop the model allowing for the estimation of light-attenuation-at-depth and temperature profiles, and their inclusion in a geolocation framework. This opens new potentialities in the field of oceanographic analysis of tagging data, in terms of both location and mapping.

Keywords: Kalman filtering and smoothing, vertical structure, oceanographic habitat.

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ICES CM 2008/P:14

Migration of a high trophic level predator, the salmon shark, between distant ecoregions

Kevin Weng, David Foley, James Ganong, Christopher Perle, George Shillinger, and Barbara Block

Knowledge of how animals move through the environment, and the characteristics of habitats they select, are essential to understanding the ecological functions they fulfil in each habitat, which in turn is necessary to predict responses to environmental change. High trophic level organisms are known to exert structural influences through the foodweb, so understanding the range, migration, and foraging strategy of abundant predators is necessary to understand ecosystem function. In this study, satellite telemetry is used to monitor the behaviour of salmon sharks, and remote sensing to characterize their environment, thereby obtaining both animal behaviour and habitat data. Salmon sharks undertook long-range migrations from coastal Alaska throughout the entire eastern North Pacific Ocean, reaching the California Current waters of the USA and Mexico, as well as pelagic waters as far west as Hawaii. Quantitative movement analyses to determine speed, path straightness, and first passage time revealed focal area behaviours in northern and southern regions, with transiting behaviours at mid-latitudes. Behavioural indices were correlated with regional habitat characteristics. Individuals migrating to a highly productive southern region stayed longer than those moving to a low-productivity region. The combination of multiyear time-series of animal behaviour with synoptic environmental data allows us to understand how the habitats that animals select differ from each other, the key factors influencing habitat selection, and the likely responses to change.

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ICES CM 2008/P:15

Spatial dynamics of white sharks in Australian waters

B. D. Bruce, R. W. Bradford, and T. Patterson

Satellite-based data collection technologies have provided enormous improvements in our understanding of the spatial dynamics, movement pattern, habitat preferences, and behaviour of sharks across a variety of ecosystems. Satellite tracking of white sharks in Australian waters has revealed broad-scale movements across their Australian range and across the Tasman Sea to New Zealand. Sharks moved through depths to 970 m and temperatures of 6.1–25.1°C, ranging from southern Australian waters to the tropics. Broad-scale movements were not restricted to adult and subadult sharks (>3.0 m), with 1.9–2.1 m juveniles covering distances of thousands of kilometres, making cross-ocean basin excursions and dives to >900 m. Within this broad-scale mixing, common patterns are emerging with sharks showing two primary behavioural modes—travelling and temporary residency. Residency sites (hotspots) were relatively few, with evidence of strong site fidelity by individuals across a range of time-scales, including highly repetitive seasonal behaviour. Sharks travelling between residency sites sometimes show common movement pathways. Residency sites were generally feeding areas that are either permanent (e.g. seal colonies) or ephemeral (fish spawning areas), but in the latter case seasonally predictable. In some cases residency behaviour by sharks has identified previously unknown centres of biological activity that now provide additional opportunities for research on ecosystem dynamics in these areas. We are integrating the emerging acoustic tagging data (based on a national coastal network of listening stations) and environmental data to model movement, behaviour, and distribution of white sharks in Australasian waters.

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ICES CM 2008/P:16**Complex migration tracks from Atlantic bluefin tuna tagged off Nova Scotia, Canada**

Benjamin Galuardi, Francois Royer, Walt Golet, John Neilson, and Molly Lutcavage

Atlantic bluefin tuna (*Thunnus thynnus*) have long been known to cross ocean basins, but an understanding of their migration to and from specific foraging grounds is limited. In 2005 and 2006, we deployed a total of 37 pop-up archival tags (PSATS) on Atlantic bluefin tuna with a median estimated weight of 250 kg off southwest Nova Scotia. The majority of fish were caught and released in the same location. Thirty-two tracks from 1–11 months in duration were recovered. We estimated the most likely migration paths and confidence regions using sea surface temperature-inclusive, state-space Kalman filtering, and bathymetric correction. The corrected tracks allowed us to assess duration of occupancy in mesoscale oceanic regions. Our spatial analyses indicated that despite being similar in size and foraging habits, these fish exhibited remarkable variability in their movement patterns, including two round trips, transatlantic migrations, some that entered the Gulf of Mexico (eight fish), and four showing return trips to the Nova Scotia tagging area. Several fish travelled to the area east of the Charleston Bump and south of Bermuda, and to the New England seamounts. These results indicate that during the putative spawning period, some large, mature Atlantic bluefin occupy a known spawning area (Gulf of Mexico) while others were located in distant oceanic regions or near the Gulf Stream. In late winter and spring, some individuals spent significant portions of time in oceanic regions that were as warm as known spawning areas (sea surface temperature >24°C). These results contrast with findings from smaller individuals tagged in the Gulf of Maine in 2002–2003, where more homogeneous movement patterns were observed.

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ICES CM 2008/P:18**Poster****Life in the big blue box: studying the marine life of European eels**

David Righton

European eel (*Anguilla anguilla*) catches, like those of *A. japonica* and *A. rostrata*, have declined dramatically in recent times. The stock is now judged to be outside safe biological limits and requires a recovery plan. The potential of European eel stocks to recover is uncertain, however, because the processes that determine the reproductive potential of the stock are not fully understood. In particular, very little is known about the marine ecology of eels, and how biological, ecological, and environmental factors affect the migration success of silver eels and leptocephali. Eeliad is a four-year, EU-funded research project to investigate the ecology and biology of European eels during their marine migrations. The project will integrate and take advantage of significant recent improvements in sophisticated scientific methods (telemetry, population genetics, molecular diagnostics, otolith microchemistry, and advanced numerical modelling) to address long-standing uncertainties in eel biology such as oceanic behaviour, the location, and timing of spawning, stock demographics/panmixia, and the role of environment in determining recruitment success. The information provided by the Eeliad project will resolve some long-standing questions about the biology of European eels and, by doing so, contribute to the development of tools for fishery managers that will enhance the prospects of sustainable management of eels.

Keywords: eels, migration, satellite tags.

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ICES CM 2008/P:19**Poster****Integrating new and old tagging technologies for Atlantic halibut**

Shelley Armsworthy, Steve Campana, and Kurtis Trzcinski

A three-year traditional tag-recapture study for all sizes of Atlantic halibut (*Hippoglossus hippoglossus*) was conducted on the Scotian Shelf and southern Grand Banks, Canada. Over 2000 halibut were tagged with T-bar anchor tags between 2006 and 2008. Currently, 125 halibut have been recaptured, at both short (<1 km) and long (566 km) distances from their release sites. However, tracking is low in spatial and temporal resolution. We plan to use pop-up satellite archival tags (PSATs) and acoustic tags to complement our current understanding of halibut movement and behaviour. For the first time in Atlantic Canadian waters, a PSAT was successfully deployed on a large Atlantic halibut (150 lb and presumed to be a female). Released on the

tail of the Grand Banks off Newfoundland, the tag was attached to the halibut for just over six months (June–December 2007). PSAT results indicate halibut have a narrow temperature preference (3 and 5°C), and they make rapid ascents and descents (~500 m per day). It also appears that halibut may spend extended periods in the water column. These results demonstrate the value of conducting future PSAT tagging to complement information from traditional tagging. We also anticipate including Atlantic halibut in the suite of species to be monitored by the Ocean Tracking Network (OTN).

Keywords: Atlantic halibut, t-bar anchor tagging, pop-up satellite archival tagging, OTN.

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ICES CM 2008/P:20 Poster

Integrating sightings surveys with static and towed acoustic monitoring to investigate responsive, seasonal and interannual changes in cetacean distribution in the English Channel

Al Kingston, Alice Mackay, Simon Northridge, Renee Swift, and Nick Tregenza

Surveys for cetaceans often include both visual and acoustic methods, but we have also combined static passive acoustic monitoring with a mobile survey platform. The advantage of combining these methods is that it allows a broader range of questions to be addressed than is traditionally possible using a single platform survey. We report on a low-cost survey for common dolphins and harbour porpoises in coastal waters along the south coast of Cornwall in the UK over two winter seasons, combining normal methods of visual and towed acoustic monitoring with static acoustic monitoring devices (T-Pods). Our aim using this combined methodology was to compare the relative density of the two main cetacean species in the study area between years, through seasons and within the survey area, while also addressing the extent to which distribution is affected by the deployment of a new type of acoustic deterrent device (STM DDD-02), potentially suitable for bycatch mitigation. We employed the same 18-m purse-seiner to conduct towed hydrophone and visual surveys in 2006 and 2007. We also deployed static acoustic monitoring devices (T-Pods) for roughly six weeks per year within an area of relatively high cetacean density, and a string of tanglenets with two DDDs [?Q1] for a total of four treatment periods. Control and treatment periods were monitored by T-Pods and by combined visual and towed acoustic surveys. Results suggest an area of relatively high porpoise and dolphin density during winter along the Cornish coast, an outmigration from the region of both species during April and an aversion to the DDDs that is inversely related to distance. The combined approach allows us to examine aspects of dolphin and porpoise behaviour and migration at spatial scales that would not have been possible given the limited budget had we used a single survey vessel.

Keywords: sightings survey; acoustic monitoring; cetacean distribution; migration.

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ICES CM 2008/P:21 Poster

LIDAR survey of menhaden population in Chesapeake Bay

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A significant concern was expressed recently about the status of Atlantic menhaden, one of the most important exploited species in Chesapeake Bay. Standard stock assessment methods are not suitable for estimation of menhaden status in the Chesapeake Bay owing to the migratory behaviour of the menhaden population. A promising technique to provide estimates of absolute abundance of menhaden is airborne light detection and ranging (LIDAR). A pilot study of LIDAR effectiveness in detecting and quantifying menhaden schools in Chesapeake Bay was conducted in 2006 and 2007. Initial LIDAR calibration was conducted through measuring target strength of individual menhaden in a tank in aquaria conditions. The LIDAR was then installed on small aircraft and series of flights were made, covering the upper, middle, and lower Chesapeake Bay. LIDAR was able to detect schools of menhaden both located near the surface when visible to the naked eye and below the surface when not visible. LIDAR depth penetration was dependent on water turbidity and varied between 5 and 13 m, with lowest penetration levels in the upper bay and highest in the lower bay. Estimates of menhaden abundance in surveyed areas were made by expanding the number of fish within the LIDAR measurement area to the total surveyed area. Results of the pilot study indicate that LIDAR can be used for menhaden school detection and absolute abundance estimation. However, absolute abundance could be underestimated when schools are located deeper than maximum penetration depth.

Keywords: Atlantic menhaden, aerial survey, LIDAR, absolute abundance.

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Poster

Atlantic cod (*Gadus morhua* L.) in the Baltic Sea visit hypoxic water briefly but often

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Prolonged exposure to hypoxia decreases the growth and predatory performance of fish. Hypoxic events are observed with increasing frequencies in lakes, coastal regions, and deeps of semi-enclosed seas. In order to understand how predatory fish can cope with hypoxia, and whether there are behavioural mechanisms to counteract hypoxia-induced decrease in growth and food consumption, the individual behaviour of fish in the presence of hypoxic water was measured *in situ*. Electronic archival tags measured individual depth experience, and subsequently depth experience was converted to oxygen experience by applying measured vertical profiles of oxygen saturation. Atlantic cod in the vertically stratified Baltic Sea spent about a third of their time at oxygen saturations below 50%. However, maximal residence time per visit in such hypoxic water was limited to a few hours. Hence, the fish visited hypoxic waters briefly but often, probably to feed on benthic organisms which are usually burrowed but had to emerge because of lack of oxygen in the sediment. Hence, hypoxia in the lower part of the vertical range of the cod probably increased food consumption. This dynamic is not necessarily visible in individual-level laboratory experiments or population-level surveys, but has to be accounted for when relating hypoxic events to changes in growth and food consumption.

Keywords: cod, behaviour, hypoxia, oxygen thresholds.

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Poster

Vertical movements of Atlantic cod (*Gadus morhua*) in the North Sea and the Baltic Sea

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Fish behaviour has profound effects on catchability, yet knowledge of fish behaviour is underutilized when fish survey data are interpreted. In particular, the vertical movements of fish determine their accessibility to trawl and acoustic gears. In addition, vertical movements have a significant effect upon the target strength of roundfish that have closed swimbladders, because swimbladder size or tilt angles change as fish move up or down in the water column. In consequence, trawl and acoustic surveys designed to assess the abundance and biomass of fish populations suffer from bias. This bias may vary from place to place and between seasons and years. We used electronic data storage tags to record individual depth experience of Atlantic cod in the North Sea and the Baltic Sea, with the aim of assessing the impact of vertical behaviour on the probability of capture and on *in situ* swimbladder size in these two systems. In general, most fish were negatively buoyant on the seabed and only in neutral buoyancy in the upper part of daily vertical range. However, vertical behaviour, and consequently catchability to trawl or acoustic gears, varied both between day and night, seasonally and between regions. The significance of these differences in assisting the development of more accurate trawl and acoustic surveys is discussed.

Keywords: cod, vertical behaviour, buoyancy, swimbladder, catchability.

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