

Theme Session Q

Use of data storage tags to reveal aspects of fish behaviour important for fisheries management

ICES CM 2006/Q:01

Extraction of daily activity pattern and vertical migration behavior for the benthic fish, *Lophius americanus*, based on depth analysis from data storage tags

Rodney Alan Rountree, Joachim Paul Gröger, and David Martins

Depth (pressure) and temperature measurements recorded on a data storage tag were examined from a single Atlantic goosefish, *Lophius americanus*, tagged on Georges Bank on 9 December 2003 and recaptured 192 days and 113 km away off Cape Cod, Massachusetts on 18 June 2004. The monkfish exhibited a strong pattern of periodic vertical movements ranging from 4 to 209 m (mean=75 m) with durations of 96 to 912 minutes (mean 225 minutes). A total of 43 vertical movements were recorded averaging 1.6 movements per week. Two periods of frequent daily movements were recorded. The first period occurred over six weeks in February and March during a transition from deep (180 m) to shallow water (150 m), while the second period apparently occurred as the fish descended into the Great South Channel and then ascended up the western slope into the inshore waters of Cape Cod over a five-week period in May and June. The rate of ascent and descent were similar with means of 1.0 m/minute and 1.2 m/minute, respectively. Vertical movements occurred primarily between 0000 h and 1200 h (81%), with peaks at 0300 h and 1000 h. Using this example, we demonstrate how depth changes in benthic fish can be used to conservatively infer activity patterns and to estimate the rate of occurrence of both vertical and horizontal migration events.

Keywords: behavior, monkfish, activity pattern, data storage tag, geolocation, selected tidal stream transport.

Contact author – Rodney Rountree: *Marine Ecology and Technology Applications, Inc. (META Inc), 23 Joshua Lane, Waquoit, MA 02536, USA [tel: +1 508-540-6970, e-mail: rrountree@fishecology.org].*

ICES CM 2006/Q:02

Habitat occupation of cod in the eastern Baltic: non-random selection in a dynamic environment

Craig Mills, D. Righton, H.-H. Hinrichsen, S. Neuenfeldt, and K. Andersen

The advent of data storage tags (DSTs) now makes it feasible to resolve horizontal and vertical movement of marine fishes and, by integrating these movements with

environment data, understand the relationship between fish behaviour and their habitat. The aim of this paper is to describe a GIS-approach to the interpretation of the habitat selection of cod. As a case study, we have analysed the movements of cod in the Baltic Sea, where cod egg survival is restricted to the deeper, more saline (>11) basins of Bornholm and the Gdansk Deep. First, we used a novel geolocation method to reconstruct the movement paths of cod released in 2003, 2004, and 2005. Second, for each movement path, the suitability of the environment for spawning (based on oxygen, salinity, and temperature) was compared to the conditions cod would have experienced had they moved at random. The results show that most cod undergo a switch from a pelagic to a demersal habit during the spawning season, and restrict their horizontal movements to the areas in which egg survival is likely to be maximised. This remarkable transition in behaviour during the spawning season demonstrates a strong link between individuals and their environment, and suggests that cod are capable of selecting habitat in order to optimise their reproductive success.

Keywords: Data storage tags, habitat selection, Baltic Sea, cod, GIS, random walk.

Contact author – Craig Mills: *Centre for the Environment, Fisheries and Aquaculture Science, Lowestoft Laboratory, Lowestoft, Suffolk NR33 0HT, UK [tel: +44 1502 524 327, e-mail: craig.mills@cefasc.co.uk].*

ICES CM 2006/Q:03

Designing fish-tagging programmes to understand fish movements and population dynamics

Julian Metcalfe, D.A. Righton, and E. Hunter

Large-scale fish tagging programmes are becoming more popular as fishery managers realise the importance of including spatial structure in assessment and management models. Two recent EU-funded projects on plaice and cod have shown how information from electronic tags can be integrated with large mark-recapture tagging programmes to gain new insights and add value to historic tagging data. Highlights have been the demonstration of unexpected population sub-structuring in plaice, and the realisation that cod behaviour is very variable in response to regional environments. Success does not come without planning and management; of staff, of data, and of expectations. We share our experiences from the last 10 years of electronic tagging, and review those of others, to provide an up-to-date analysis of what makes a good tagging programme, and how to get the most from it.

Keywords: data storage tags, migration, behaviour, tagging.

Contact author – Julian Metcalfe: Centre for Environment, Fisheries and Aquaculture Science, Lowestoft Laboratory, Lowestoft, Suffolk, England UK [tel: +44 1502 524 352, fax: +44 1502 513 865, e-mail: j.d.metcalfe@cefas.co.uk].

ICES CM 2006/Q:04

“All men have need of the cods (sic)” (Homer, the Odyssey) or “An overview of the results of the EU-CODY SSEY project”

David Righton

Cod stocks in European waters are in serious decline, prompting the adoption of Recovery Plans in some areas, e.g. the North Sea, and similarly serious management measures elsewhere, e.g. Barents Sea, Baltic Sea. CO-DYSSEY (Cod spatial dynamics and vertical movements in European waters and implications for fishery management) is an EU-funded R&D project that involves nine European research institutions in eight different countries. The aim of the project is to improve understanding of the behaviour and distribution of cod in the NE Atlantic in support of stock assessments and Recovery Plans. Over the last four years, members of the CO-DYSSEY research team have tagged over 2500 cod with electronic tags in four different regions (North Sea, Barents Sea, Baltic Sea, and Icelandic plateau). To date, over 450 tags have been returned, yielding tens of thousands of days of data. The results challenge previously held assumptions regarding migratory behaviour, feeding behaviour, and the tolerance of cod for extreme environmental conditions. We have been able to derive rates of migration, stock mixing and availability to fisheries from the tag data. The results of the CODYSSEY project are of value to fish biologists and fisheries managers at national and international level.

Contact author – David Righton: Coordinator of the CODYSSEY project, Centre for the Environment, Fisheries and Aquaculture Science, Lowestoft Laboratory, Lowestoft, Suffolk, UK, NR33 0HT [tel: +44 1502 524 359, fax: +44 1502 526 359, e-mail: david.righton@cefas.co.uk].

ICES CM 2006/Q:05

Geolocation of tagged Baltic cod using the particle filter

Ken H. Andersen, A. Nielsen, U. H. Thygesen, and H.-H. Hinrichsen

A central ingredient in the analysis of data from archival tags is geolocation, namely the determination of where the tagged fish has been and when. We will present how the “particle filter” can be used to that end. The particle filter is a standard statistical method and a generalization

of the Kalman filter. The use of the particle filter for geolocation has several advantages: 1) it provides uncertainty estimates of the geolocation at each timestep; 2) it is possible to estimate parameters, e.g. swimming velocity; 3) it takes errors in the measurement from the tags specifically into account. The use of the particle filter will be illustrated with examples from tagged Baltic cod. The information used for the geolocation is the bathymetry and the salinity provided by a hydrodynamic model.

Contact author – Ken H. Andersen: Danish Institute for Fisheries Research, Charlottenlund Castle, DK-2920 Charlottenlund, Denmark [tel: +45 3396 3375, e-mail: kha@dfu.min.dk].

ICES CM 2006/Q:06

Return migrations of Atlantic cod (*Gadus morhua* L.) to the North Sea evidenced by archival tagging of cod off the eastern Skagerrak coast

H. Svedäng, D. Righton, and P. Jonsson

Due to the decline of local stocks in the Skagerrak, juvenile cod abundance in the eastern part of the Skagerrak may have become dependent on transport of recruits from offshore sources. Cod offshore spawning in the eastern North Sea has been thought to be supplying recruits to the Skagerrak coastal areas, as transportations of eggs and larvae of cod and other gadoids in this direction were substantiated. It has also been suggested that juvenile fish originating from offshore spawning locations migrate off the coast when they reach a certain size or age.

Here we show that cod (>40 cm) tagged off the Skagerrak coast migrated to the North Sea during the spawning period. Furthermore, retrospective positioning from retained archival tags by astronomical derivations of time-logged ambient light measurements depicted a migratory route to the eastern North Sea during the spawning season, and back again to the Skagerrak later in spring. The light intensity-based geolocations were cross-validated with tidal location methods and experienced temperature at depth of the tagged fish, supporting the view of a North Sea-bound migration route during the spawning period. These findings give a strong behavioural signal with bearing on population separation and divergence in marine fish species.

Keywords: Skagerrak, North Sea, cod, light geolocation, TLM.

Contact author – Henrik Svedäng: Swedish Board of Fisheries, Institute of Marine Research, P.O. Box 4, SE-453 21 Lysekil, Sweden [tel: +46 523 18 723, fax: +46 523 13 977, e-mail: henrik.svedang@fiskeriverket.se].

ICES CM 2006/Q:07

Integrating across scales: Linking tagging technology with molecular genetics to gain insight in environmental influence on the horizontal migration patterns of two stocks of cod in Northeast Atlantic waters

Kathrine Michalsen and Torild Johansen

Cod is economically the most important species for Norwegian fisheries. While cod are depleted in most areas, like Canadian waters, Greenland, and the North Sea, the Northeast Arctic cod (NAC) is thought to be the most abundant cod stock in the North Atlantic. On the other hand the partially co-occurring Norwegian coastal cod (NCC) stocks have decreased in numbers in recent years. In addition, several reports on climate change have caused a growing concern about their impact on life in the ocean climate. For effective management it is necessary to be able to partition the variability in fish populations into environmental, genetic, and fisheries effects. In the present study we have combined molecular genetic methods and data from electronic data storage tags (DST) of cod (*Gadus morhua* L.) to study distribution, behaviour, and environmental factors experienced by individuals of the two stocks of this species in the Northeast Atlantic.

Keywords: combined molecular genetics, data storage tags (DST), distribution, behaviour, environmental factors.

Contact author – Kathrine Michalsen: Institute of Marine Research, P.O. Box 1870, Nordnes, NO-5817 Bergen, Norway [tel: +47 5523 8500, fax: +47 5523 8687, e-mail: kathrine@imr.no].

ICES CM 2006/Q:08 – Withdrawn

ICES CM 2006/Q:09

Fish migration in oscillating stratified water masses

Boonchai K. Stensholt, Åge Høines, and Yoshie Kasajima

Time-series records from data storage tags (DST) attached to Northeast Arctic cod and Greenland halibut are investigated together with hydrodynamic and hydrographic features at specific locations to reveal the spatial and temporal variation in fish migration patterns, which may change the availability of fish to survey gears. From spring to autumn, some Greenland halibut, at depths of 500–800 m, were exposed to a persistent diurnal fluctuation of temperature between subzero and 5.5°C. Tidally-induced topographic trapped waves with diurnal (K1) frequency were indicated along the Barents Sea escarpment, where the transition zone between warm Atlantic water (AW) and cold (–0.5°C to 0.5°C) Norwegian Sea Arctic Intermediate Water (NAIW) is at 500- to 700-m depth. Asymmetry in the temperature diurnal pattern showed a gradual increase followed by a rapid drop. This event may be related to the displacement mechanism of

stratified water masses together with the fish diurnal migration pattern in synchrony with tidal motion. The pattern indicates that fish migrated seawards off the slope and were pelagic part of the day, thus being unavailable to bottom trawl. Up to three weeks in April, some tagged cod had low vertical activity at a depth exposed to semi-diurnal tidal fluctuations of the transition layer between 100 and 200 m, where cold coastal waters lie on top of warm Atlantic waters. Along the southern coast of the Barents Sea, a strong semidiurnal tide can generate baroclinic coastal Kelvin waves causing vertical motion of the pycnocline; thus, semidiurnal fluctuation of temperature was observed.

Keywords: data storage tag, diurnal, migration, shelf slope, tide.

Contact author – Boonchai K. Stensholt: Institute of Marine Research, PO Box 1870, Nordnes, NO-5817 Bergen, Norway [tel: +47 5523 8667, fax: +47 5523 8687, e-mail: boonchai@imr.no].

ICES CM 2006/Q:10

Vertical distribution and variable mortality rates of adult cod (*Gadus morhua*) in Icelandic waters

Vilhjálmur Thorsteinsson and Ólafur K. Pálsson

Distribution of adult cod in Icelandic waters and its availability to fisheries is studied by special tagging experiments using conventional tags and electronic archival tags aimed at the spawning component of Icelandic cod stock 1995 to 2004. The method consists of tagging adult cod on spawning grounds during the spawning season, releasing a relatively large number of cod with conventional tags and with a sub-sample double-tagged, adding electronic-archival tags. This method provides more recaptures for each release group than when only using electronic-archival tags, thus obtaining more information on population parameters, distribution of the fishery, and migrations within or outside the area of the fishery. The results show considerable time spent by some cod at deeper levels than the main distribution of the fishery, and an association of foraging with thermal fronts. Occurrences of deep types of feeding migrations and recapture rates vary between spawning components with indications that the more cod forage in deeper waters, the lower the probability of capture by the fisheries outside of the spawning season. In Icelandic waters, the feeding migrations of adult cod from continental shelf areas to deeper waters (below 200 m.) thus seem to reduce the availability of adult cod to the fishery.

Keywords: *Gadus morhua*, double tagging, migrations, availability, mortality.

Contact author – Vilhjálmur Thorsteinsson: Marine Research Institute, Skúlagata 4, 121 Reykjavík, Iceland [tel: +354 575 2107, fax: +354 575 2001, mobile: +354 863 5442, e-mail: villi@hafro.is].

ICES CM 2006/Q:11 – Withdrawn

ICES CM 2006/Q:12

Behaviour of homing Atlantic salmon (*Salmo salar*) recorded by data storage tags (DST) inserted in wild trawl-captured salmon in the Nordic Seas, NE Atlantic

Marianne Holm, Jens C. Holst, Jan A. Jacobsen, and Johannes Sturlaugsson

An inter-Nordic tagging study including Norway, Faroes, and Iceland was carried out in the Nordic Seas in 2002–2004. The aim was to study various marine life history traits of Atlantic salmon such as winter habitats, diurnal patterns of vertical migration and feeding activities, and temperature preferences. 734 salmon were captured with a special “salmon trawl” with a device for live fish capture attached to the codend. After capture the salmon were observed in a tank and care was taken when selecting fish for tagging (< 20% loss of scales, stable swimming behaviour). The tags were placed in the body cavity. “I-button” tags (Dallas Semiconductor) recording only temperature and depth and temperature recording tags (Star Oddi “Milli”) were used. In total 406 tagged fish were released. Five salmon, all captured during spring/summer in the Norwegian Sea, were recaptured in or close to a river after 400–1300 km of travel. 439 days of observation were recorded in tags. 14–20 days of relative inactivity after release were observed for all recaptured fish. Salmon stay mostly in the uppermost 5–10 m, making excursions into deeper layers. Extensive diving activity periods are common, but diving depths (from 85 m to ~280 m) and the number of dives per time unit vary considerably. A consistent diurnal pattern probably related to feeding activities could be observed. DSTs are an invaluable tool for studying marine life history traits of salmon. The relatively frequent dives below 20–50 m might make the salmon more vulnerable to interception by mid-water trawls in some areas than previously believed. The number of observation days obtained from each tag balances the relatively high costs of tags.

Keywords: Data storage tagging, Atlantic salmon, North East Atlantic, diurnal behaviour, migration, homing.

Contact author – Marianne Holm: Institute of Marine Research, P.O. Box 1870 Nordnes, NO-5817 Bergen, Norway [tel: +47 5523 6892 (dir.), +47 5523 8500 (switchb.), fax: +47 5523 6379, e-mail: Marianne.holm@imr.no].

ICES CM 2006/Q:13

The swimbladder under pressure

Jeroen van der Kooij, David Righton, Kathrine Michal- sen, Vilhjalmur Thorsteinsson, Henrik Svedang, Peter Wright, and Stefan Neuenfeldt

Atlantic cod (*Gadus morhua*) is a highly adaptive boreal species with a broad distribution through different eco- systems in the North Atlantic. Diet, environmental fac- tors and population dynamics vary enormously through- out this range, and behaviours are therefore extremely plastic. However, the behaviour of cod will always be constrained by physiology, be it temperature tolerance, swimming speeds or buoyancy control. Cod, like other gadoids, are physoclists, i.e. they have a closed compli- ant swimbladder that can be filled or emptied in order to achieve neutral buoyancy at any depth. Pressure changes caused by vertical movements lead to expansion and compression of the swimbladder as individuals ascend or descend respectively. Over time, changes in the volume of the swimbladder will occur so that individuals can maintain neutral buoyancy with the minimum effort. Here, we have used data collected by cod tagged with electronic tags and released in four different ecosystems of the NE Atlantic to investigate the neutrally buoyant descent rates of cod that are moving from shallow resi- dence depths to deeper ones. First, we describe the pat- terns of vertical movement and rates of descent in the recuperation period following tagging, when the swim- bladder is re-inflating to achieve neutral buoyancy at capture depth. Using this recuperation behaviour as an indication of swimbladder inflation during extreme depth changes, we describe similar patterns of natural behav- iour during medium-term transitions from shallow to deeper depths as cod migrate between different areas. Third, we assess the significance of behaviour of this kind, its relationship to environmental variables and how it varies between regions and seasons. Finally, we calcu- late the buoyancy status of cod during these transitory phases and assess the implications for acoustic surveys.

Contact author – Jeroen van der Kooij: Centre for the Environment, Fisheries and Aquaculture Science, Low- estoft Laboratory, Lowestoft, Suffolk NR33 0HT, UK [tel: +44 1502 524 416, fax: +44 1502 513 865, e-mail: jeroen.vanderkooij@cefias.co.uk].

ICES CM 2006/Q:14

Partitioning on-bottom and off-bottom behavior: a case study with yellowtail flounder off New England

Steven X. Cadrin and Joshua Moser

Archival tags deployed on yellowtail flounder indicate distinct periods of on-bottom and off-bottom behavior. Geolocation of fish during tag deployment requires accu- rate identification of periods when tagged fish were on- bottom (defined by a semi-diurnal tidal cycle of depth observations) and episodes of off-bottom movements

(identified as an abrupt decrease in depth, interrupting the regular tidal cycle).

Thirty-seven archival tags, deployed on yellowtail flounder off New England, had multiple off-bottom movements. These distinct vertical movements were typically in evening hours, lasting several hours. Tidal features (e.g., amplitude, time of high tide) can be derived from the time series of depth records and used for geolocation. However, failure to clearly differentiate on-bottom from off-bottom records confounds estimates of daily tidal features by confusing vertical movements with tidal cycles. Analyses were conducted to develop an automated algorithm for identifying vertical movements, exploring patterns of off-bottom movements and deriving daily tidal features. Quality assurance protocols are described to assess the veracity of time, pressure and temperature records; and to optimize tag settings and specifications such as sampling frequency and resolution of measurements.

Keywords: data storage tags, archival tags, electronic tags, movement, geolocation, yellowtail flounder.

Contact author – Steve Cadrin: NOAA/UMass Cooperative Marine Education & Research Program, 706 South Rodney French Boulevard New Bedford, MA 02744-1221, USA [tel: +1 508 910 6358, fax: +1 508 910 6396, e-mail: steven.cadrin@noaa.gov].

ICES CM 2006/Q:15 – Withdrawn

ICES CM 2006/Q:16

Development and application of ‘FRAFOS’ tags for studying fish movement

Conrad W. Recksiek, G. Fischer, H.T. Rossby, S.X. Cadrin, and P. Kasturi

The newly developed FRAFOS (‘Fish’ RAFOS) tag reverses the signal of conventional acoustic tags by receiving acoustic signals from moored sound sources, allowing triangulation of geographic position during deployment on fish. We report progress in developing this archival tag for geolocating juvenile and adult demersal shelf fishes. The tag and navigation system are similar in concept to those of isopycnal RAFOS floats, in which arrival times of low frequency tones broadcast from anchored sources are archived and later retrieved for retrospective positioning. The principal differences between FRAFOS tags and RAFOS floats is that the tag is small enough to be attached to or implanted in fish about 50 cm or larger, and the tags must be recovered from the tagged fish to download data. Prototype FRAFOS tags are being deployed on adult yellowtail flounder, *Limanda ferruginea*, on Georges Bank to study movement in the vicinity of an offshore area that is closed to fishing. Deployment of sound sources will be on or along the edge of the continental shelf where detection ranges appear to be on the order of 100 to 120 km for sources generating a sound pressure of 180 dB re 1 microPascal. The size of the prototype is governed by dimensions of a cy-

lindrical housing which functions as the hydrophone. Within this is a full-custom 0.5 micrometer receiver chip, memory chip, timing crystal, two batteries, and pressure sensor (temperature sensor is on-chip). The receiver chip consumes 21 microWatts at 3 V with an expected data storage life of several months to two years.

Contact author – Conrad Recksiek: Fisheries, Animal, and Veterinary Science, University of Rhode Island, Kingston, RI 02881, USA [tel: +1 401-874-2334, fax: +1 401-874-6160, e-mail: conradw43@hotmail.com].

ICES CM 2006/Q:17

Description and validation of an improved algorithm for automated archival tag geolocational estimation based on the matching of satellite SST and *in situ* temperature data: application to striped marlin (*Tetrapturus audax*) in the North Pacific

Frank J. O’Brien, M. L. Domeier, C. H. Lam, and V. M. Tsontos

Satellite archival tags are being widely used to study the migratory dynamics and habitat utilization of diverse marine fish species. However, positional estimates inferred from recorded light level data recorded by tags and light-based algorithms are notoriously unreliable at estimating latitude, particularly around the time of equinoxes and around the equator.

Matching sea surface temperature (SST) measurements between those sampled by the tag and those observed by satellites has been identified as a means of refining latitude estimates. But the use of SST to help resolve latitude has been hindered by the difficulty in manually matching data series. Here we present an algorithm (PSAT Tracker) that performs the task of SST matching automatically within a GIS environment. Given certain assumptions about swimming speed, the program selects multiple, matching candidate points for each day of SST data and then costs the most efficient path without recourse to a serial solution. A validation exercise examining PSAT Tracker applied to three striped marlin (*Tetrapturus audax*) double tagged off of Baja California with both GPS (SPOT) and archival tags is undertaken. A comparative assessment of the performance of PSAT tracker relative to light-based methods and increasingly used statistical approaches (Kalman filter) is also presented.

Keywords: fish migratory behavior, tagging studies, SST, algorithm, geolocation, latitude estimation, GIS, striped marlin.

Contact author – Vardis M. Tsontos: Department of Biological Sciences, University of Southern California, 3616 Trousdale Parkway, AHF M-235, Los Angeles, CA 90089-0371, USA [tel: +1-213-740 1810, fax: +1-213-740 8123, e-mail: tsontos@usc.edu].

ICES CM 2006/Q:18

Understanding the behavioural rules of free-ranging marine vertebrates from analysis of electronic tagging data: the Eutopia project

David W. Sims and Julian D. Metcalfe

Predators such as marine fish search widely for resources and concentrate activity in productive habitats with associated high biodiversity. Hence, they have the potential through their movement and behaviour patterns to signal wider-scale changes in marine ecosystem status. Shifts in the availability of lower-trophic-level resources or community structure are likely to lead to concomitant alterations in spatial distribution and abundance of predators. Therefore, knowledge of top predator movements, activity, and habitat selection in relation to variations in the physical and biotic environments will help resolve how natural and human-driven environmental changes affect marine populations. However, there is a lack of understanding about where marine top predators go, what they do when they get there, and, crucially, *why* they select particular habitats over others at certain times. Understanding the 'why' question is possible if the behavioural processes, or decision criteria, underpinning observed movements across dynamic ocean landscapes can be identified. This paper will describe how behavioural rules can be identified from electronic tagging data using simulation and modelling approaches and will introduce a new initiative aimed at tackling this issue, the European Tracking of Predators in the Atlantic – the Eutopia project. The key focus of this project is to determine behavioural 'rules' underlying movements in relation to dynamic changes in habitat quality, whether there are similar (general) behaviour patterns among diverse marine vertebrates, and how a knowledge of these can be used to develop predictive spatial-population models.

Keywords: behaviour, electronic tags, movement analysis, habitat selection, decision-making, simulations, modeling.

Contact author – David Sims: Marine Biological Association of the UK, The Laboratory, Citadel Hill, Plymouth, PL1 2PB, UK [tel: +44 1752 633 227, fax: +44(0)1752 633 102, e-mail: dws@mba.ac.uk].

ICES CM 2006/Q:19 – Poster

The proximity of Pacific cod to the sea floor: An investigation into the availability of Pacific cod to survey bottom trawl gear

Daniel G. Nichol, T. Honkalehto, G.G. Thompson, and D.A. Somerton

The proximity of Pacific cod to the seafloor was examined, using archival tags released on and recovered from cod in the eastern Bering Sea, Alaska, in an effort to ascertain the percentage of cod in the water column that are available to bottom trawl surveys. The archival tags recorded timed depth and temperature data at 15- or 30-

minute intervals. The vertical distance of a cod off the bottom was computed by subtracting tag depth from an estimated bottom depth. Bottom depths were estimated as the maximum depth recorded during each 24-hr day.

Bottom depth values for periods between successive maximum 24-hr tag depths were estimated using linear interpolation. These estimations assume that cod approach the seafloor at least once every 24-hr period, and that cod do not undergo vertical migrations up or down bottom slopes. As such, we narrowed our analysis to 11 tagged cod that were recaptured in areas of flat bottom bathymetry, and only analyzed data recorded within 1 month prior to recapture (n=29,462 depth recordings). Pacific cod maintained short vertical distances away from the seafloor that often differed between day and night. Nearly 95% of the daytime tag recordings occurred within 10 m of the seafloor. Average effective net heights for survey bottom trawls currently used in the eastern Bering Sea and Alaska Gulf/Aleutian groundfish surveys are approximately 2.5 and 7 m, respectively. In the absence of any behavioral responses to an approaching trawl, we would expect 50% availability for the eastern Bering Sea Survey and 90% availability for the Gulf/Aleutian surveys.

Keywords: Pacific cod, vertical migration, diurnal, survey bottom trawl.

Contact author – Daniel G. Nichol: National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, Washington 98115-0070, USA [tel: +1 260 526-4538, e-mail: dan.nichol@noaa.gov].

ICES CM 2006/Q:20 – Poster

Vertical migrations of saithe/pollock (*Pollachius virens*) in Icelandic waters: extent and duration of directed runs, diel and seasonal differences

Sigurður Thor Jonsson and Hlynur Armannsson

Data storage tags implanted in saithe/pollock (*Pollachius virens*) in Icelandic waters have revealed diel and seasonal differences in vertical migrations which influence catchability and have implications when saithe are studied as acoustic objects. The poster presents results with additional tag returns based on a data set of hourly recordings of depth and temperature from 32 saithe. Measurements were made at 10- and 1-minute intervals for a subset of the measurement series retrieved from $\frac{2}{3}$ and $\frac{1}{2}$ of the saithe recaptures, respectively. The data are analysed in relation to previous results on diel and seasonal differences in saithe vertical movement (which are up- and down-ward). The duration and vertical extent of upwards and downwards directed runs are analysed at different time scales. Results from recordings at 1-minute intervals may elucidate saithe swimming behaviour and possibly contribute to an understanding of tilt angle distributions, which in turn influence saithe acoustic backscatter strength/area.

Keywords: saithe, pollock, *Pollachius virens*, vertical migration, data storage tags.

Contact author – Sigurdur Thor Jonsson: Marine Research Institute, P.O. Box 1390, 121 Reykjavik, Iceland [tel: +354 575 2093, fax: +354 575 2315, e-mail: sigurdur@hafro.is].

ICES CM 2006/Q:21 – Poster

Distribution and migration of saithe (*Pollachius virens*) around Iceland inferred from information obtained with Data Storage Tags

Hlynur Armannsson, Sigurdur Th. Jonsson, Gudrun Marteinsdottir, and John D. Neilson

Knowledge of distribution and migration of fish populations are necessary to be able to identify and conserve stock components and thus genetic variability. Compared to other gadoid species there is very little known about life history traits of saithe (*Pollachius virens*), pollock in the NW-Atlantic, or its stock components in the NE-Atlantic. Evidence from traditional tagging has shown that saithe can be highly mobile and are capable of migrating a long distance between different waters. Experiments have also shown that saithe are very active in the water column and undertake both diel and seasonal vertical migrations. In 2000–2004 around 15,800 juvenile saithe were tagged and released around Iceland. Of these, 133 were tagged with data storage tags (DSTs, from StarOddi, Iceland) implanted in the body cavity. So far, 34 DSTs have been returned (thereof 32 usable) from saithe ranging from 3 to 5 years old and 42–72 cm at release. In this poster we will compare data from three different release sites around Iceland. These release sites differ considerably in terms of bottom topography and the hydrography of the surrounding water masses. By comparing hydrographic measurement and depth and temperature profiles of recaptured saithe, we can get a broad view of migration patterns of young saithe in the three areas over a whole year. Traditional tagging will be used to strengthen our conclusions from the data gained with DST.

Keywords: saithe, *Pollachius virens*, migration, distribution, DST.

Contact author – Hlynur Armannsson: Marine Research Institute, Borgir v/Nordurslod 600 Akureyri, Iceland [tel: +354 575-2311, fax: +354 575-2315, e-mail: hlynur@unak.is].

ICES CM 2006/Q:22 – Poster

Use of pitch and roll DST to distinguish between pelagic and along-the-bottom vertical migrations of Greenland halibut

Ole Thomas Albert and Tone Vollen

DSTs record the depth of the fish, but not its height above the bottom. We used DSTs that also recorded the 3-D orientation of the fish (pitch and roll), in order to distinguish pelagic swimming from swimming along the bottom for Greenland halibut (*Reinhardtius hippoglossoides*) in the Barents Sea. More than 200 adult Greenland halibut were tagged and so far 15 recaptures have been analysed.

The poster discusses three aspects of the recordings:

- (1) The pitch angle of the fish during ascent/descent was compared with the steepness of the bottom topography of the area.
- (2) The roll angle of the fish was compared with the previously assumed vertical orientation of Greenland halibut during pelagic phases.
- (3) The variability of both pitch and roll during different sections of the depth trajectories were compared with video analyses of flatfish swimming behaviour in the lab, as well as with hydrodynamic considerations that both predict a change in variability between periods of swimming along the bottom and periods of swimming away from the bottom.

Keywords: Greenland halibut, DST, pitch and roll.

Contact author – Ole Thomas Albert: Institute of Marine Research, POB 6404, NO-9294 Tromsø, Norway [tel: +47 7760 9736 / 9962 6002, e-mail: oleta@imr.no].