International Symposium on Bio-logging Science

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ABSTRACTS

Oral presentations

Opening session

OI-1: Bio-logging as a booster for ecophysiology

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Ecophysiology is the science of "how animals work" in their natural environment. Considering the huge variety of conditions that wild animals face on earth, which often appear extreme and impossible to mimic in the laboratory, their many physiological adaptations provide a source of scientific information which has remained largely unexplored. Moreover, to determine the impact of environmental changes on animals, a research focussing on the main scheme "from the genes to the function" is certainly appropriate. We do need an ecophysiological approach to understand for example how animals are able to face a drop in resources.
Until recently, however, the physiological information that we could get with a minimum perturbance upon animals free ranging in their natural environment was extremely limited. The availability of miniaturized loggers has completely changed the situation. For example, heart rate and regional body temperatures can be monitored on birds diving far at sea, which bring new light on the physiological adjustments related to long-term apnea.
Further progress is also made in new techniques, such as those using stable isotopes, which could be combined with bio-logging. Finally, considering the implantation of bio-loggers in free-ranging wild animals, we need a special concern on what is ethically acceptable.

OI-2: Genesis and evolution of Bio-logging Devices: l963-2002

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Bio-logging devices have become an integral part of many studies on the behavior, physiology and ecology of marine vertebrates. In the beginning, 1963, a time depth recorder (TDR) was designed to measure time and depth of freely diving Weddell seals in the Antarctic.
These were the first devices used to obtain detailed information on underwater activity of an aquatic animal. They recorded data for one hour. Since that time there has been a steady evolution of this type of recorder. During the 1970's a revised TDR recorded the diving activity of fur seals and Weddell seals over a period of 14 days. The inventive pace quickened in the 1980's with the emergence of microprocessors. Although their recording time was still limited to a duration of two or three weeks, the miniaturization process made possible the logging of several additional variables. By the 1990's data were being collected over a period of several months, and the value of this extended recording time was exemplified by the logging of every dive during the

entire migratory cycles of elephant seals. The next revolution occurred with the inception of satellite transmitters that made it possible to determine precisely where an animal was on the planet. This remarkable ability to incorporate measurement of spatial distribution was soon augmented by a third revolution, the use of mountable videocameras ("crittercams") on the animals themselves. With this arsenal of bio-logging devices many problems and issues about aquatic animals are being addressed that were only dreams for the first generation of biologists studying the marine activities of vertebrates.

OI-3: Marine predators at South Georgia: between a rock and a hard place. Understanding how marine predators exploit their environment

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Early studies of marine predators relied upon visual recording methods to investigate provisioning behaviour. However, the past few decades have seen the growing use of micro-electronics to address increasingly sophisticated questions about the 'who', 'where', 'when', 'what' and 'how' of foraging, with only the 'why' remaining elusive. With the continuing development of instrumentation, modern packages are ever-smaller in size and can be deployed on an ever-increasing list of species; in addition, some are now relatively inexpensive such that they can be used routinely as monitoring tools.
A number of important challenges still exist in the use of bio-logging to investigate trophic interactions in ecosystem contexts (including application to fisheries and environmental management and conservation), these include:

- acquiring samples large enough for statistical analysis;
- replicating study sites and/or populations in order to characterize population and species behaviour;
- collecting simultaneous data from multiple sensors or devices in order to interpret foraging behaviour;
- acquiring key collateral data on prey and environment at appropriate spatial and temporal scales to understand foraging dynamics in context;
- managing, analyzing, displaying and interpreting the necessary volumes of data in an effective way.

We illustrate approaches to address some of these challenges from recent studies of the South Georgia marine ecosystem, where the oceanographic regime is complex and highly variable and where top predator species operate at a wide variety of spatial and temporal scales.

OI-4: New steps of the bio-logging science

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Direct measurements of diving behavior for free ranging animals by the animal mounted depth recorder had been commenced from the weddell seal in the Antarctica in 1965, and essential advances of the diving behavior study have been achieved in 1980s by using some mechanical TDRs. Since late 1980s digital data loggers have been developed and studies of animal behavior came to a new era as computer linked science. Sophistication and miniaturization of the tools have been progressively achieved after millennium. Now we can measure animal posture, movements, position, environment in fine scale using highly-advanced digital micro-loggers for understanding of the animal behavior, physiology, and ecology. However as data integration precedes and amount of data increase, we have to develop further advanced techniques of data processing and analysis with aid of computer science. We have to extract important information from complicated data and create new idea about the living animals and the nature. Information-technology is more important for processing and analyzing of gigant data and another bio-informatics are required. In conjunction with new technology field biology will come into another new era.

Cetacean session

OI-6: Identifying habitats and habits of endangered large whales with satellite-monitored radio tags

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In one decade, the OSU Marine Mammal Program has instrumented 197 large endangered whales (104 blue, 91 humpback, 11 fin, 46 right, 12 bowhead, 14 gray, and 19 sperm whales) in 7 seas/oceans, ranging from equatorial to both Polar Regions. Each experiment revealed new discoveries, including feeding, migration and reproductive areas, often correlating with bathymetric features and oceanographic conditions. Individual whales show considerable variability. Some species use limited areas, while others range widely, providing insights into foraging ecology.
Tracking for 10.5 months has been achieved with small (nearly implantable) tags, which incorporate long-dispersant antibiotics to reduce the risk of infection. We have guidelines about whales not suitable for tagging: calves, whales <8m and those showing emaciation, infection, or cyamid infestation. Tag data are useful in: examining anthropogenic impact (disturbance/mortality from shipping, fishing, and seismics), identifying and characterizing seasonal habitats, migration corridors, temporal/spatial/social issues, and mitigation measures. Smaller future tags will be more reliable and sophisticated in studying movements, habitats, behavior, physiology and environment to reduce human impact and promote depleted species recovery.

OI-7: Individual acoustical characteristics of the free-ranging and captive Yangtze finless porpoises (*Neophocaena phocaenoides asiaeorientalis*)

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Sounds of eight individuals of the Yangtze finless porpoises (*Neophocaena phocaenoides asiaeorientalis*) (six males and two females) were recorded individually in Shishou Baiji Semi-natural Reserve, Hubei, China, in June 2002. Individual sounds of five animals were recorded in open waters, and the other three individuals were recorded in net-circles. Additionally, individual recording of sonar signal events, body movements, swimming speed and depth of three captive Yangtze finless porpoises (one male and two females) were conducted using an acoustic (W20-A, Little Leonardo, Tokyo, Japan) and an acceleration data loggers (PD2GT, Little Leonardo, Tokyo, Japan) in Baiji Dolphinarium, Wuhan, China, in November 2002. The datalogger system was attached by a suction cup (Canadian Tire corp.) for more than 40 hours on the animals. The acoustic datalogger could record ultrasonic signals with less contamination of low frequency noises by a 100-kHz high-pass filter. The differences of click emission rate existed among all the animals. The circadian rhythms of respiration, swimming, and sound production of captive animals were documented. Correlation between body movement and sonar pulse structure is also recognized.

OI-8: Instrumentations of North Atlantic cetaceans: triumphs and disasters

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Many questions pertaining to stock identification and ecology of North Atlantic cetaceans are best addressed by instrumenting whales with satellite transmitters and time-depth-recorders. Instrumentation methods include capturing small cetaceans in nets and attaching tags, where as in the case of larger cetaceans, tags are launched using crossbows, air-guns, and poles. Attachment methods have included suction cups, nylon pins, and stainless steel and titanium spears with barbs. Miniaturization of transmitters has considerably improved tag longevity and helped to answer questions that would have been impossible to obtain with other methods. There are, however, still issues pertaining to long-term tag reliability and power consumption. Attachment of small tags on

belugas and narwhals has reliably provided 6 months of tracking data, and under optimal conditions, tags have performed well for more than 12 months. Transmitter attachment on large cetaceans is a more unpredictable process; methods include embedding the entire tag under the skin, or embedding a harpoon head or barbed spear, with the tag externally exposed as an epoxy cast, steel can or tethered float. Despite the attachment challenges there are several cases where tags have performed exceptionally well on minke, fin and bowhead whales, demonstrating the attachment method was not the primary factor in tag longevity.

OI-9: Deep-water predation by narwhals revealed by satellite telemetry

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Diving behavior of narwhals was examined using satellite-linked time depth recorders (SLTDRs) deployed on three sub-populations in the Canadian High Arctic and West Greenland. The number of dives to different depths and time allocation within the water column were examined between three seasons. Clear differences were observed between two distinct wintering grounds in Baffin Bay. Narwhals occupying a northern wintering ground spent most of their time between 200-400 m (29 dives/day, SD 9) and narwhals in a southern wintering ground spent most of their time at depths >900 m (15 dives/day, SD 6). A model of travel time and occupancy time at different depths was built using standard binned histogram dive data, and was used to investigate trade-offs of different foraging strategies. Observations on seasonal area use (95% kernel range estimates), coupled with a bioenergetic model, were related to data on Greenland halibut in Baffin Bay. Significant differences in Greenland halibut density and length frequency were correlated with predation levels and dive behavior on wintering grounds. The use of location and diving data collected from satellite telemetry provided sufficient information for a detailed examination of seasonal behavioral changes, habitat use, and effects of predation by separate assemblages of narwhals in the Baffin Bay ecosystem.

Seal session

OII-1: Seeing the forest for the trees: making sense of large and complex data sets derived from bio-logging devices

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Our ability to transmit and log information about animals and their environment is increasing rapidly. These remarkable advances in technology bring with them concomitant requirements for the processing and analysis of increasingly large and complex data sets, and often the ability to collect data outstrips our ability to interrogate them fully. This paper examines the types of approaches that can be used for several types of data sets, from the deceptively simple time/depth records through to more complex sets that integrate behavioural, environmental and geographic information. Particular attention will be paid to the range of biological questions that can be asked of these data sets, because even the simplest dive/depth records can make significant contributions to a range of physiological, ecological and behavioural topics. However, fully quantitative analysis of these data is still in its infancy and there is an urgent need for greater collaborations between biologists and specialist statisticians. Some of the approaches that show considerable promise are agent-based models (ABM), Monte Carlo simulations, neural networks and spatially-explicit complex systems using Geographic Information Systems (GIS). Examples of each of these approaches applied to pinniped data sets are discussed.

OII-2: The behavioural adjustments for variation in prey availability detected by using bio-logging data: the case of the Antarctic fur seals

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We developed a behavioural indicator of prey availability at the level of the individual dives measured with data loggers. The behavioural indicator of prey availability was well correlated with independent measures of prey abundance. Using the indicator within the framework of optimal foraging theory, we examined both how the prey of Antarctic fur seals varies through time and how the fur seals themselves adjusted their time budgets to maximize the mean rate of energy intake by organizing their foraging activity within and between bouts. Foraging in Antarctic fur seals conformed to many of the predictions from energy rate maximizing behaviour: the net rate of energy intake by fur seals declined with time spent in a patch, the rate of energy intake on leaving a patch declined as food availability in the environment declined, and the time spent in patches increased as food availability declined. We concluded that Antarctic fur seals were able to adjust their behaviour to track highly variable prey distributions and densities. The simple decision about when to leave a patch in relation to current environmental prey availability appears to be responsible for allowing fur seals to maintain saturation of the foraging rate as food density declines.

OII-3: Blubber and buoyancy: Estimating body condition from simple dive characteristics

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Examining foraging success and energy assimilation at a fine scale is problematic. Especially in the case of long-ranging animals, we need some measure of prey consumption and the associated change in body condition that can be continuously recorded while at sea.
We examined the changes in passive vertical drift rates of southern elephant seal pups throughout their first trip to sea, and developed a mechanistic model to estimate body condition from these rates. We simulated the effects of errors in each model parameter. Seawater density, body volume and surface area caused negligible errors, while varying the drag coefficient could cause errors in estimated lipid content of more than ± 10 %.
There was a strong correlation between estimated and actual lipid content (measured using labelled water), and errors were generally within ± 2 %. The model indicates that after the initial transit phase, seals had reduced their lipid content to ~ 19 - 29 % compared to ~ 34 - 42 % at the start of the trip. This implies lower daily net energy expenditures than previously estimated. In summary our results suggest that this simple method may allow us to quantify and allocate energy assimilation of free-ranging marine vertebrates more accurately in space and time.

OII-4: Relating behavioural signals derived from dataloggers to foraging success models for southern elephant seals

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Marine mammals are consumers of large quantities of prey within the ocean environments in which they live; however, little is known about where and when individuals encounter and capture their prey. To estimate temporal and spatial patterns of prey consumption by the wide-ranging southern elephant seal (SES - *Mirounga leonina*), we used behavioural, geo-location and physiological data collected from 25 female SES from Macquarie Island. We first estimated the change in the rate of vertical drift in the water column during the passive phase of 'drift dives'. This change was then used as a surrogate for lipid assimilation because drift rate, and hence, buoyancy, is a function of the lipid:lean tissue ratio in a seal. Next, we estimated the proportion of

days per spatial grid cell that seals were assimilating lipid. We used these proportions to weight the time spent per grid cell to estimate relative foraging success. Finally, previous analysis of fatty acid signatures in the blubber indicated spatial and temporal variation in the proportion of squid and fish found in the diet. All results were combined in a simple energetic model to produce an estimate of prey consumption by SES within the regions of the Southern Ocean south of Australia during the post-lactation and post-moult foraging trips.

OII-5: Marine mammals as platforms for oceanographic sampling: a "win/win" situation for biology and operational oceanography

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The development and deployment of logging and telemetry equipment on wide range marine animals has provided a wealth of data on their movements and behaviour. We can now predict, within reasonable limits, where many species go, which parts of the water column they will visit and when they will go there. But we need to know not only about the behaviour of animals at sea but also more about the environment through which they move in order to understand their biology and the potential risks to their population status. We are also increasingly being made aware of the need for near real-time monitoring of ocean processes for long-term weather and climate analyses and forecasting. Developments in sampling and data retrieval devices have made it possible to create a synergy between the biological studies of marine vertebrates and oceanographic studies that describe and predict changes in the ocean atmosphere system. We can use larger marine species as platforms of opportunity to gather detailed oceanographic information that is extremely valuable to both communities. Animals can collect information from logistically difficult areas, at fine temporal and spatial resolution at relatively low cost. I will discuss the technological opportunities that are currently available, the results of ongoing projects and one "proof of concept" study with the hope of stimulating interest across the technical, oceanographic and biological communities for such an approach.
It seems certain that the need for timely, high resolution oceanographic information needed for the understanding the distribution of marine animals and for the development of increasingly fine resolution physical models will grow more rapidly than the funding available to collect that data. By using animals as platforms, we can close the gap.

OII-6: Foraging ecology in subantarctic fur seals in relation to environmental conditions: concurrent use of bio-logging and satellite oceanography

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This study investigated the foraging behaviour of lactating subantarctic fur seals breeding on Amsterdam Island, Indian Ocean, in relation to seasonal and interannual variations in sea surface temperature (SST) of the surrounding waters over 3 consecutive years (1995 to 1997). Foraging habitat and diving activity were investigated by the concurrent use of ARGOS satellite transmitters, direction recorder, and time depth temperature recorders (TDRs), deployed on 34 individuals during the first trip after parturition (n=7), later in summer (n=18) and in winter (n=9). Sea temperatures recorded by TDRs in conjunction with IGOSS SST database were used as a locational cue to estimate foraging range. Foraging habitat of lactating females was associated with the SubTropical Front (SST=14.2C) where their main prey, myctophid fish, are known to be abundant. The organisation of the foraging trips, in terms of diving activity, showed seasonal changes but remained similar among years. During the first trip after parturition, females foraged within the STF, 60 to 130km from the island and showed a constant diving activity throughout the trip. Later in summer, when the STF was 300km south from the island, all females but one travelled on a straight south-east route without diving (suggesting they target a known area), then concentrated their diving activity on the STF during 50% of the foraging trip duration, and then came back to the island while still diving. In winter, the 14C surface isotherm

was 200km north from Amsterdam Island and the SST gradient was very low. Females increased their foraging range up to 530km, and there was no evidence of females concentrating their diving activity within a given area/SST, suggesting that they did not encounter dense patches of prey. In winter, seals also increased the diving effort probably in response to a decrease in food resource availability.

OII-7: Individual variability in grey seal (*Halichoerus grypus*) diving behaviour highlighted by the use of the *Time Allocation at Depth* Index (*TAD*) in satellite tracking

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The *Time Allocation at Depth* (*TAD*) Index was recently devised in order to compress and analyse diving data obtained from TDRs and Satellite Relay Data Loggers (SRDLs) deployed on marine mammals. This dimensionless, depth- and duration-independent index indicates the depths in which the animal concentrated its dive-time, given that a minimum time is necessary to reach the maximum dive-depth (referred to as travelling time). When most diving time is spent at the shallowest depths of the dive, the TAD tends to 0. It is 0.5 if the seal spends equal time at all depths encountered (V-shape dive), and tends to 1.0 when all time except travelling time is spent at the maximum depth (U-shape dive). This index was computed in SRDL's deployed on 14 grey seals in 1999 and 2002 in Brittany, France. Maximum dive depth and duration, TAD and sea bottom depth were used to describe the individual diving behaviour of the seals during their trips at sea. We observed a great individual variability in the diving behaviour of different seals performing similar trips in the same areas. This could reflect the variability in foraging strategies developed by the grey seals in the periphery of their range.

OII-8: A Digital video/data recorder for monitoring behavior and multi-dimensional movements of marine mammals at sea

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We have developed a digital video/data recorder and operating software for monitoring behavior and multi-dimensional movements of marine mammals at sea. The system consists of a small, aluminum housing for the micro-controller, lithium batteries and sensors for pressure, swim speed, compass bearing, ambient temperature, ambient dissolved oxygen, light level, tilt, pitch and roll. Digital video and audio are compressed on-the-fly and stored on a mini-hard drive with a recording duration to 30 hours. The micro-controller has eight analog-to-digital converters at 12-bit resolution, four serial input/output ports and 24 digital input/output ports. A second housing contains the miniature black and white video camera with near-infrared light emitting diodes (LED) as a light source. The video camera is mounted on the animal's head and connected by a thin cable to the housing containing the micro-controller. The miniature GPS module with active antenna is mounted on the seal's head adjacent to the video camera. An accelerometer that is mounted near the tail and connected by a cable to the main housing senses flipper motion and is used to determine stroke frequency. This new generation of video/data recorder will be used initially to study the foraging behavior of free-ranging Weddell seals in Antarctica.

OII-9: Dive depths of Weddell seals in relation to vertical prey distribution as estimated by image data

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To better understand the foraging behavior of diving animals it is important to monitor aspects of the animal's environment, including prey distribution, which may influence their behavior. However, prior to recent technological advancements, monitoring the distribution of prey immediately surrounding a diving animal had been impossible. We attached newly developed Digital Still picture Loggers (DSLs) to 8 free-ranging Weddell seals (*Leptonychotes weddellii*) at breeding colonies in McMurdo Sound, Antarctica, from November to December 2000. The DSLs provided depth data and several thousand underwater images taken from the seals' perspectives. Some of these images clearly showed scattered prey-like objects directly in front of the seal. Using image processing software, the images were converted to a 256 gray-scale and the prey-like objects were identified according to their brightness ratio and counted. Finally, a "prey index" was calculated for each image and the vertical prey distribution along the seals' dive paths were compared with the seals' dive depth. Seals frequently dove to depths greater than 250 m where the prey index was both higher and exhibited a wider range. We concluded that the seals' dive depths might be affected by the vertical distribution of prey, which appeared to be aggregated in shoals at deeper depths.

OII-10: Effects of ice hole location on foraging behavior: Results from the reconstructed three-dimensional dive paths of free-ranging Weddell seals

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Multi-data sampling on free-ranging animals appears as a valuable tool to investigate foraging effort in relation to environmental features. In order to investigate the foraging ecology of Weddell seals, we deployed simultaneously three types of data loggers on five free-ranging individuals. Field experiments were conducted between November-December 2000 at two sites (siteI and II) in McMurdo Sound, Antarctica. Depth gauges measurements indicated that siteI seals, following immersion, had to follow the island slope to reach deep waters, while siteII seals could dive from ice holes opening directly over deep waters. The 3-dimensional dive paths of seals were reconstructed using 3MPDT loggers (depth, swim speed, 3-dimensional geomagnetism) and D2GT loggers (depth, 2-dimensional gravitational acceleration). Prey abundance along diving paths was obtained using DSL logger (digital still camera). Upon selection of a specific foraging area, seals descended using straight paths. Once at the point of maximum depth, siteII seals foraged mainly at the bottom part of dives and returned straightly to the surface, while siteI seals followed an upwardly-orientated foraging route that led them back towards the ice hole, the final part of the ascent following a straight path. Seals appear to change their foraging strategy according to ice hole location.

OII-11: The environmental basis for fur seal ecology - using digital video cameras to establish prey encounter rate

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We have used a digital video camera (Wild Insight Ltd) to record the prey-field ahead of diving Antarctic fur seals. Images were recorded at frame rates varying from 0.3 - 15 Hz. Antarctic krill, the primary prey of these seals, were apparent in a large proportion (up to 28%) of images, although there were significant differences between individual seals and between seasons of observation. Images were catalogued according to krill presence in terms of reliability of image identification and estimation of krill biomass. The proportion

of images showing krill recorded per dive was used as a proxy for prey encounter rate. In some, although not all, cases this measure could be seen to decrease over the duration of a dive bout. Ultimately, this will allow the investigation of optimality models of diving behaviour in terms of variation in diving parameters according to both prey depth and prey encounter rate.

Bird session

OIII-1: The heart of the matter: using heart rate data loggers to estimate metabolic rate of free-living birds

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Field metabolic rate (FMR) of animals is required in order to: i) determine the metabolic costs of activities such as foraging (diving for aquatic birds), breeding, migration, ii) test the "energetics" explanation of some natural behaviour patterns of birds, iii) determine the total energy and food requirements of a population, iv) estimate the effect of top predators on their prey species and the possible effects of harvesting of the prey species on the predators. Two main methods have been used to obtain estimates of FMR: stable isotopes [doubly labelled water (DLW), ^{13}C labelled bicarbonate]; heart rate (f_H). Both methods should be carefully validated with each species of bird to be used and both require the recapture of the experimental animals. With DLW, the duration of the experiment is usually limited to a few days or weeks. However, with f_H, data can be stored electronically for over a year and, if the logger is implanted, it has little or no effect on the behaviour and reproductive success of the bird. This presentation will outline the calibration and validation methods that have been used for the f_H method with diving and migrating birds and discuss the implications of the values of FMR obtained.

OIII-2: Bio-logging at the isolated dive hole: The diving physiology and behavior of emperor penguins

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Short-term deployments of bio-loggers on emperor penguins (*Aptenodytes forsteri*) diving at an isolated dive hole have recently documented more details of this model of penguin diving physiology. The primary prey is the sub-ice fish, *Pagothenia borchgrevinki*. Prolonged gliding (> 10 s) does not occur during dives. Despite 10 to 30^{o}C declines in peripheral tissues, deep body temperatures remain near 36-38^{o}C during dives. Heart rate is 150 to 200 beats per min (bpm) immediately pre- and post-dive; it decreases to 20-50 bpm during dives. Deep-dive (150-200 m) behavior occurs when birds are allowed around-the-clock access to the dive hole. The prominent bradycardia and lack of core hypothermia during dives suggest that regulation of organ perfusion is the primary mechanism of blood O_2 conservation. These findings are most relevant to the diving of emperors in pack ice since surface intervals and out-of-water exits at the isolated dive hole are typical of known behaviors of emperors in pack ice. In the future, use of the isolated dive hole and advances in bio-logger technology should allow refinement of behavioral techniques for at-sea studies, as well as, otherwise infeasible, physiological investigations of pressure adaptation and O_2 store utilization during dives.

OIII-3: Changes in body temperatures reveal the benefit of huddling during pairing and incubation in emperor penguins

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Male emperor penguins entirely assume the incubation and then have to fast for 4 months during the Antarctic winter. We have previously shown that huddling is decisive in enabling them to decrease their metabolic rate and thus to succeed in their task. Is this energy saving due to a decrease in body core temperature?
In mid-pairing, 5 males were equipped with data loggers which recorded core, subcutaneous and external temperatures every 10 s during 2.5 months.
During pairing, core temperature gradually decreased from 39 to 36°C. During egg exchange, there was a 1°C increase and core temperature remained at 37°C all throughout the incubation.
To assess the benefit of huddling, we found that "huddling core temperature" was 0.5°C below "non huddling core temperature" during pairing. By contrast, "huddling subcutaneous temperature" was 0.6°C higher than "non huddling subcutaneous temperature".
In case of egg abandon during the incubation, "huddling core temperature" decreased by 0.8°C whereas "huddling subcutaneous temperature" increased by 0.7°C. In case of success, core temperature remained almost constant at 37°C. In 60% of the huddles, external temperature exceeded upper critical temperature (20°C) and could reach 37°C. Accordingly, by huddling together, the males increased their shell temperature and reduced their core temperature.
Therefore, by lowering their core temperature of 3°C during pairing and keeping it low during the incubation, male emperor penguins save energy. Furthermore, this energy saving is enhanced when the birds are into a huddle.

OIII-4: Non-random flights in the Benguela: linking fine-scale foraging behaviour of Cape Gannets as assessed by GPS tracking with remote-sensed patterns of marine productivity

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Pelagic seabirds search for food in an apparently featureless environment. Their distribution patterns are nonetheless far from random, and numerous species have been shown to gather at specific oceanographic features such as fronts and eddies. However, how birds select these zones, and how they adapt their fine-scale searching behaviour according to the quality of the different oceanic areas remains poorly understood. We equipped 100 Cape Gannets (*Morus capensis*) breeding on Malgas Island and Bird Island (Lambert's Bay), South Africa with GPS data loggers. Devices (40g, 65x35x12 mm) were attached with waterproof Tesa tape to the upper side of the tail. The GPS data loggers recorded the position (accuracy at least +/- 10m) of the birds every 10 sec during foraging trips lasting for 8 to 60 hours. All journeys were conducted within 200 km of the breeding sites i.e. within the Benguela upwelling zone. The abiotic variability of this highly dynamic coastal zone was assessed synoptically via remote-sensing of sea surface temperatures and chlorophyll concentrations (NOAA, SeaWifs). Combining bird tracks and satellite data we explore the links between Cape Gannet fine-scale searching behaviour (foraging path length, sinuosity and flight speeds within travelling zones and foraging zones) and marine productivity.

OIII-5: Behavioural adjustments to foraging constraints in a large pelagic seabird

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Central place foragers face several constraints while foraging in the marine environment, among which travelling costs and food allocation to self-feeding versus chick provisioning are determinant features that are expected to shape the organization of the foraging trip. In order to examine how seabirds may optimize their time at sea in the lights of these constraints, we monitored the time-budget of breeding Cape gannets, *Morus capensis*, foraging off the coast of South Africa, using miniaturized motion sensors. Birds spent on average 58% of their trip resting at the sea surface around the middle of the trip (longest rest = 2.28 ± 0.41 h). Bouts of feeding activity occurred mainly at the beginning and end of the trip (in 81% of birds). Such bimodal feeding activity may reflect the separation between self-feeding and provisioning behaviour. This and the extended rest at the sea surface around the middle of the trip are proposed to serve at fractionating the food mass ingested, as well as optimizing the digestion processes. In addition, gliding accounted for 21.7% of the total flying time. Two flight modes were distinguished: a flapping-dominant mode during feeding and a flap/glide mode during commuting.

OIII-6: Where, what and why? – Details on the foraging behaviour of Northern Gannets revealed by new GPS technology and multi-logger usage

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To get a detailed insight into the foraging behaviour of Northern Gannets (*Morus bassanus*) on a temporal and spatial scale, we deployed different logger-types in various combinations on individual birds. With stomach-temperature-loggers we registered feeding events and fast-response time-depth-temperature-recorders were used to collect fine-scale data on diving behaviour, time-activity-budgets and sea temperature. Moreover, a newly developed GPS-logger was used to determine precisely the birds' positions.
In August 2002, we deployed GPS-loggers on 8 chick-rearing gannets at Bass Rock, Scotland. Of the 8 birds 4 carried a time-depth-recorder and 4 a stomach-temperature-logger additionally. We collected data on 120.4h of at-sea-activity. This yielded in a total of 905 GPS-positions with a precision between ±1.5 - 19m. By overlaying the positional information with the behavioural and oceanographic data collected with the other loggers we could characterise the utilised marine areas with respect to sea temperature, foraging effort and foraging success, and thus elucidate the foraging decisions of Northern Gannets searching for prey. In the talk, the results will be presented in detail and the potential of the methods for future research will be outlined.

OIII-7: Foraging strategies of breeding seabirds studied by bird-borne data loggers

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Our research group has devised and manufactured a data loggers which, glued on the back of a bird, can detect and memorise the direction in which the bird is heading during a flight. Given the birds' constant cruising speed, the memorised data can be used to reconstruct the whole flight path. Subsequent versions of this direction recorder, equipped with new sensors (depth meter and flight sensor), were used for investigating the foraging

behaviour of several species of breeding marine birds (Brünnich's Guillemot, Common Guillemot, Razorbill, Northern Gannet, Kittiwake, Blue-footed Booby). The data recorded at different colony sites allowed us to identify the birds' feeding grounds and record the most relevant events occurring in the foraging trips, including the duration of the trips, total flight time, number and duration of the stops where feeding actually occurred, dive profiles and diving behaviour. Differences in the foraging strategies between sexes and between incubating and brooding birds were also investigated.

OIII-8: Life history of seabirds and the marine environment: what have we learned with bio-logging

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Seabirds have a low fecundity, they start breeding at old age and have high adult survival. The reasons for such an extreme demography are generally searched in the marine environment and often attributed to the poor, patchy and unpredictable marine environment on which they rely. The distances between the colony and the resources also put constraints on the amount of energy seabirds are able to invest in reproduction. Here I review how, with the development of biotechnologies, it has become possible to relate the foraging constraints imposed by the marine environment, to the processes of allocation of resources and their consequences for the demography of seabirds, especially petrels and albatrosses. In particular I examine the foraging ecology of adults during breeding as well as during sabbatical years, of immatures and juveniles birds, studied with various telemetry systems for localisation (GPS, Argos transmitters, geolocation systems) and for recording behavioural and physiological parameters (activity recorders, stomach temperature sensors, heart rate recorders). These studies have allowed us to understand how birds forage in relation to the environmental conditions and to the distribution of resources, and how they acquire energy for breeding in relation to the energetic costs of foraging at very long distances.

OIII-9: Foraging behaviour of penguins in relation to the hydrothermal structure: seasonal and inter-annual variation

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How foraging seabirds depend on oceanographic features has focused considerable attention. We investigated the three-dimensional exploitation of the water mass in relation to hydrographic features in deep and long distance foragers such as King penguins by using time-temperature depth recorders (TDRs) and satellite tracking. This work is a part of a long term research program carried on the foraging ecology of deep diving predators in relation to climatic variability at two localities of the South Indian ocean (Crozet and Kerguelen Islands).
At Crozet, the foraging movements and diving behaviour of King penguins were examined over the annual cycle (n = 51 birds). Annual change in foraging patterns were monitored over 9 summer seasons (1994-2002). Data on seawater temperatures were obtained from TDRs records and the SST IGOSS database. Over the seasons, the penguins utilised specific oceanic areas and clearly adjusted their diving behaviour to the water mass explored. The foraging mode was related primarily to large-scale seasonal changes in hydrographic structure and prey availability. The day-by-day analysis of diving patterns revealed that large differences occurred in the use of the water column, at meso to small scale. The penguins generally avoided to dive in the surface mixed layer (80 to 140 m) and mostly dived in and below the thermocline. At any time of the year the birds minimise dive depth by travelling toward areas of thinner surface mixed layer. During years of abnormally warm water (1997 and 1998), the penguins foraged much more far and dived deeper. Large changes in at-sea distribution and diving behaviour are discussed in conjunction with the interannual variability of frontal area positions and the variations in the thermal gradient.

OIII-10: The use of penguins to study oceanographic features east of Kerguelen Islands, Southern Ocean

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Development of miniaturized sensors allows the use of diving vertebrates as autonomous platforms for oceanographic sampling.
Temperature-depth recorders (TDRs) and Argos satellite transmitters were attached to 18 king penguins from Kerguelen Islands during February-March 1998 to 2001. Temperature and pressure were sampled with resolutions of 0.18°C and 2 m, respectively. A comparison of TDRs temperature records with a CTD showed an absolute difference of 0.14 °C. The penguins traveled to average distances of 304 km and dived to average depths of 148 (n = 10530 dives). Temperature data of each dive were assigned a position using Argos fixes, filtered, and placed on a fine scale 3D grid.
The obtained dataset was sufficient for mapping the upper ocean's thermal structure over the foraging area, a poorly sampled but productive region. The temperature map, at 100 m depth, clearly shows a cold tongue orientated northwest which closely follows the eastern shelf break, indicating advection of cold subsurface water originating from the south. This feature, not clearly seen from sparse early data, provides a better understanding of regional water circulation and helps explain the high primary productivity over the Kerguelen Plateau. Interannual vertical temperature sections obtained from the penguins are also compared.

OIII-11: Rapid response loggers reveal interplay between marine physics and seabird behaviour

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In the marine environment, the distribution of primary producers and higher trophic levels is strongly dictated by the physical characteristics of the water column. Typically, life concentrates in regions with strong gradients in temperature or density ("fronts"). Top predators target fronts and their high biomass of prey. Until now, studying the interaction between predators and the physical environment has been hindered by inadequate instrumentation. The response times of temperature-depth recorders have been too slow to accurately measure the external environment. We describe the first deployments of a new rapid-response temperature-depth logger on two diving seabirds, common guillemots *Uria aalge* and European shags *Phalacrocorax aristotelis*. The two species were feeding in contrasting water types: the common guillemot fed exclusively in stratified, deeper water; the European shag fed inshore in very mixed, shallow water. Both species showed diurnal and tidal patterns of foraging depth. A method for correcting temperature data for the time lag in the response of the sensor is presented. This technology has potential in two important ways: in providing unparalleled information on the interaction between predators and the marine environment, and as a low-cost method of obtaining high quality oceanographic data, such as tidal advection and internal wave activity.

OIII-12: Commute local: migrate global - scales of travel and foraging in albatrosses

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For several species of *Thalassarche* albatross (mollymawks) we use remote-recording data to contrast the

mutually exclusive population foraging ranges during chick-rearing with the mesoscale (basinwide) ranges during incubation and with the circumglobal migrations between successive breeding attempts. New data on migration reveal: multiple circumnavigations; consistent use of similar ocean areas on successive circumnavigations; spatial and temporal overlap with habitats used by breeding congeners from the same site; spatial but not temporal overlap with habitats used by congeners from other sites; and consistent differences between birds of different reproductive status.
Although albatrosses may forage in different areas at different seasonal and life-history stages, the environmental context (habitat) may show broad similarities and sometimes analogous ecological structure. However the prey and foraging associations may differ substantially, according to area, environment and reproductive status. Overlap with fisheries may vary markedly both within and between seasons. Particularly during migration there is potential for association with a wide diversity of fisheries with a commensurate wide range of mortality risk. Understanding the patterns of foraging by albatrosses, particularly the constraints on non-breeding individuals, is a major challenge which may hold the key to understanding the demography of their populations.

OIII-13: Satellite tracking migratory birds in East Asia

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In collaboration with American, Japanese, Korean and Russian scientists, we have satellite tracked the migration of cranes, storks, swans, geese, and hawks in Asia, including far eastern Russia, since 1991. The goal of our ongoing research is to determine the spatial and temporal migration patterns of these birds, to facilitate the conservation of both the birds and their habitats. Here, we examine migration routes, migration patterns through time, stopover sites, habitat use and conservation issues relevant to these birds. We also compared the migration patterns of birds of different ages. Focal species of cranes and the oriental white stork (*Ciconia boyciana*) which breed in various locations in east Asia used some of the same stopover sites on migration and when wintering, even when the origin of their migrations and migration routes differed. Threats to these birds include habitat alteration and loss, direct human disturbance, hunting, and poisoning. Results from preliminary investigations of Stellar's sea eagles (*Haliaeetus pelagicus*), black-faced spoonbills (*Platalea minor*) and white-naped cranes (*Grus vipio*) suggest longer migration periods in young birds, with more time spent at stopover sites. We emphasize the importance of both habitat protection over entire routes used by migratory species, and continued research into and mitigation of threats to their survival.

OIII-14: Wing stroke regulation of vertically and obliquely diving alcids

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Seabirds dive with the air in their feather and lung. So they may adjust thrust power to the buoyancy change with depth by regulating wing strokes. We studied the wing propulsion of vertically diving Brünnich's Guillemots (*Uria lomvia*) and obliquely diving Rhinoceros Auklets (*Cerorhinca monocerata*) in the wild by high-speed (32 Hz) sampling of surge (tail-to-head) and heave (ventral-to-dorsal) accelerations with bird-borne data-loggers. Dive angle was estimated with the low frequency component of surge. Forward thrust and wing strokes were estimated with high frequency components of surge and heave, respectively. The guillemot dove almost vertically. The auklets started to dive with an angle of 60 degrees and decreased the angle as they went to deeper waters. At the start of descent, both species produced a surge during each of the up-stroke and the down-stroke. While they produced a surge only during the downstroke in the bottom phase. Thus, they reduced the

frequency of thrust as they were descending deeper but they kept the frequency of wing stroke in 2 – 3 Hz. Species differences in the changes of the frequency and strength of wing stroke with dive depth will be discussed.

Reptile session

OIV-1: Activity and migration patterns for marine turtles inferred from satellite tracking, motion sensors and flipper beat recorders

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The movements and diving performance of marine turtles have now been quite widely explored through the deployment of satellite transmitters and dive computers. These instruments have revealed an array of migration patterns and diving behaviours: from directed shuttling across the oceans between foraging and nesting areas (e.g. green turtles), to broad-scale (1000s of km) ocean wanderings (e.g. leatherback turtles); from long-term residence at shallow depths (a few metres) in the case of foraging green turtles, to routine deep (> 100m) diving in leatherback turtles. Interfacing dive computers and swim speed sensors to satellite transmitters now allows the reconstruction of dive profiles for animals in remote locations, while flipper beat recorders allow the second-by-second changes in behaviour within dives to be identified. Combined with improved device attachment techniques that have allowed successful long-term deployments (> 1 year), these technological developments allow the behaviour of turtles to explored in detail over extended space (1000s of km) and time (many months or even years) scales.

OIV-2: Habitats of the adult loggerhead turtles found in the south part of Japan

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The tracking of migration routes of the Japanese loggerhead turtles have been examined with satellite tags in a few coasts of Japan since 10 years ago or so. In this paper, to make clear the habitat of Japanese adult loggerhead turtles *Caretta caretta* found in the south part of Japan, 14 turtles (7 males and 7 females) were released with the satellite tags (PTTs used the Argos system) on their back in 2000 to 2002. From these experiments the location data of 11 turtles (5 males and 6 females) were obtained. Seven turtles (5 males and 2 females) migrated to the East China Sea, 1 female did to the South China Sea and 3 relatively small females did to the Kuroshio Extension area. Namely, the Japanese loggerhead turtles had 3 different migration routes. From these results, some turtles were benthic and others were pelagic. Therefore, the Kuroshio Extension area as the pelagic habitat as well as the East and South China Sea as the benthic habitat is considered as the important conserving area.

OIV-3: Feeding-habitat use by adult Japanese female loggerhead turtles *Caretta caretta*

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The relationship between body size and feeding habitats of adult Japanese female loggerhead turtles was investigated using stable isotope analyses and satellite telemetry. Comparisons between isotopic values in loggerhead egg-yolks and prey items revealed that small females feed on planktonic animals in pelagic waters and large females feed on benthic animals in neritic waters. Satellite tracking results were consistent with these inferences and previous findings. Furthermore, since female loggerheads grow little after reaching sexual maturity and there were no significant differences in isotopic values between recruits and remigrants, female loggerheads most likely do not change their feeding habitats during the reproductive stage. Female habitat selection as a function of body size would be closely related to the recruitment and settlement of immature turtles. Female loggerheads may adopt a conditional strategy; turtles that grow faster during developmental migrations in pelagic waters stay there and reach maturity, whereas turtles with lower growth rates recruit to neritic waters and become larger feeding on nutrient-richer prey. Although the neritic turtles start reproduction later, by virtue of their shorter remigration intervals, larger body (i.e. clutch) size, and approximately the same remigration (i.e. survival) percentages, their fitness would be comparable to that of the pelagic ones.

OIV-4: Foraging ecology in breeding female leatherback sea turtles in relation to multi-scale oceanographic processes in the Atlantic Ocean: concurrent use of ARGOS satellite tracking and satellite altimetry.

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We investigated the foraging ecology in 34 female leatherback sea turtles breeding in French Guyana, Western Equatorial Atlantic Ocean, between 1999 and 2002. At sea movements were assessed by ARGOS tracking, and investigated in relation to micro-, meso-, and macro-scale oceanographic features assessed by satellite oceanography. During 32 inter-nesting movements in 2001 and 2002, females spent 10 days at sea, travelled up to 100km offshore but remained on the continental shelf (<100m deep). Turtles spent up to 60% of their time within a shallow (<20m deep) area less than 20km radius, at the mouth of the Maroni river estuary, where micro-scale physical oceanographic processes are highly dynamic. Post-nesting movements were monitored in 1999-2002 during up to 16 months and 10000km. Females showed an oceanic distribution all over the Northern Atlantic Ocean. There was no obvious migratory corridor: one animal headed North-West to Florida; five others headed North/North-West to reach the Gulf Stream where they showed clockwise/anti-clockwise movements on warm/cold border of meso-scale eddies, respectively; finally, five last animals headed straight East, as close as <500km from African coasts, and some used the Equatorial Counter Current to head back to the West. The wide oceanic distribution of leatherback sea turtles is discussed in relation to coastal and oceanic human activities.

Fish session

OIV-05: From simple measurements to complex behaviours: using miniature data loggers to learn about fish movements and behaviour in the open sea.

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Data-loggers have been used in animal telemetry since the 1960s. However, it was not until the early 1990s, that such devices became sufficiently small and robust that they could be deployed widely on marine fish, and many

thousands have been deployed on a range of species.
Continuing advances in microelectronic technology make increasingly sophisticated, "archival" or "data storage" tags available. However, while some carry out limited on-board data processing, most are essentially "simple" data recorders, spending most of their time "asleep" and occasionally "wake up" to record one or more environmental (e.g. pressure, water temperature, ambient daylight) or physiological (e.g. body temperature) variables. These variables are usually straightforward to record because they are continuously available and change comparatively slowly. Nonetheless, complex biological and environmental information can be deduced from these apparently simple time-series.
This paper describes the use of small data storage tags on a range of both teleost and elasmobranch species, and the methods developed to derive "complex" information about movement and behaviour from "simple" variables such as temperature, pressure, and ambient daylight. I will go on to describe how we are using the large amounts of data this technology makes available to construct individual-based models of population movement.

OIV-6: Behaviour of Patagonian toothfish (*Dissostichus eleginoides)* fitted with archival tags at Heard Island

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Thirty nine *Dissostichus eleginoides* were released in the vicinity of Heard Island carrying archival tags in April 2002. Since then seven have been recaptured and the depth and temperature data they recorded is analysed here. Most of the fish had periods of active vertical movement alternating with periods of relative inactivity, loosely correlated with moon phase. The direction of vertical movement was influenced by the bottom topography, with fish on the relatively shallow plateau or in the bottom of a valley only moving upwards from their resting depth, while those on the intervening escarpment moved both upwards and downwards. Major vertical movements were highly synchronised and took place between 0500 and 1100 local time.

OIV-7: Hunting and migratory movements of white sharks in the eastern North Pacific

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The aim was to determine local movements of hunting white sharks, *Carcharodon carcharias*, near a seal rookery and global movements during migration. Six adults were monitored with attached acoustic beacons that received and telemetered animal position and behavior via an array of three-acoustic-positioning (RAP) buoys moored off Año Nuevo Island, California. Migratory movements of 12 adults departing this and another rookery were tracked for 2-9 months with attached pop-up satellite archival tags. Sharks began hunting seals in October, spending 40% of the day in the 1 km^2 receptive field, patrolling within 200 m of the island and parallel to it near the surface at 30 m or less. For six weeks, they did not stray far or long from the area, were equally active at night as by day, were non-territorial, and fed infrequently. This nearshore phase ended abruptly in winter as the sharks moved offshore to a region of the subtropical eastern Pacific half way to Hawaii. An adult male went further, traveling to Hawaii where it remained until migrating back to California, only to repeat the journey the following year. Electronic tagging provides vital information on the hunting and migratory behavior of this apex predator.

OIV-8: Adaptation mechanisms of Pacific bluefin tuna to temperate waters

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Immature Pacific bluefin tuna *Thunnus thynnus orientali*s, marked with archival tags, were released near Tsushima Island in the East China Sea. A total of 31 fish were recovered and time-series data for ambient and peritoneal cavity temperatures, recorded every 128 or 256 sec, were analyzed. Our main objectives were to clarify development process of the thermoconservation ability with their growth to investigate their adaptation mechanisms to temperate cooler waters. Results as follows; mean ambient temperatures ranged from 14.9 to 20.7 ºC, which is almost within the range of their optimum temperature (14.0 to 19.0 ºC). Although the mean thermal differences between peritoneal and ambient temperatures were correlated to their body size, the increase rate decreased with their growth and the thermal difference never continued to increase infinitely. Further, the heat budget model suggests that insulation of their body develops and the estimated mean values of internal heat production decreased with their growth. This may be the reason why the thermal difference does not increase infinitely with their growth and that giant bluefin tuna makes it possible to actively swim in cooler waters.

OIV-9: Electronic tags reveal feeding and breeding migrations of Atlantic bluefin tuna.

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The successful deployment in recent years of implantable and pop-up satellite archival tags has rapidly enabled researchers to examine the movements of large pelagic fishes. The results of the on going electronic tag program in the western Atlantic called the Tag-A-Giant (TAG) are presented in this talk. This program is a collaboration between scientists from Stanford University, the Monterey Bay Aquarium and the National Marine Fisheries Service.
To date 680 electronic tags have been deployed on Atlantic bluefin tuna at four locations in feeding regions (offshore waters of North Carolina and Massachusetts, USA) and on breeding grounds (the Gulf of Mexico and the Mediterranean Sea). Over 25% of the first 300 archival tags deployed have been recovered and 85% of the pop-up satellite archival tags have provided successful downloads. Together, the data sets provide new information on the Atlantic bluefin tuna's movements. The archival data reveal that mature Atlantic bluefin make extensive feeding migrations for up to seven months into cold temperate and subpolar waters. These same individuals make shorter breeding migrations into warm temperate and tropical waters. These two ecological phases place distinct demands on the bluefin tuna's physiology. Feeding migrations of western tagged bluefin are to three major regions: the continental shelf waters of New England and North Carolina and the North Central Atlantic south of Iceland. Breeding migrations are to the Gulf of Mexico, Bahamas, Caribbean and the Mediterranean. Archival tagging data indicates that bluefin tunas often encounter the coldest temperatures during feeding migrations (3°-12°C) while maintaining endothermic muscle and visceral temperatures of 23°-33°C. During breeding migrations to the Gulf of Mexico, Bahamas and Mediterranean seas, ambient temperatures range from 23°-29° C and body temperatures occasionally approach 31°C creating a high metabolic demand for oxygen in warm waters. Immature fish have been shown to remain close to the continental shelf for one to three years post tagging. The tagging data provide the opportunity to understand the distribution of pelagic fish in relation to their changing physical and biological environments.

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OIV-10: Homing behavior and mechanism of black rockfish *Sebastes inermis*

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Rockfishes of the genus *Sebastes* in North Pacific Ocean, for example *S. inermis, .S flavidus and S. caurinus*, have homing ability to the original habitat after experimental displacements. However, homing mechanisms of these rockfishes have not been clarified at all. We conducted biotelemetry using coded ultrasonic transmitters to clarify homing mechanisms of black rockfish *S. inermis*. In this study, we focused on the visual cue and the olfactory cue of the homing navigation. In our vision blocked experiment (n=14), the elapsed time for the blind fish to home was not significantly different from that for the control fish. In our olfactory ablation experiment (n=10), all intact fish homed to their original habitat. In contrast, all ablated rockfish with vaselin in their nares did not return to their original habitats before the removal of vaselin. These results show that the olfaction is the major sensory mechanism of the black rockfish to detect the original habitat.

OIV-11: Utility of an acceleration data logger in estimation of swimming speed and depth of fish

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Red sea bream (FL 52.5cm, BW 3.61kg) was attached with an acceleration data logger (UWE-PD2GA, Little Leonardo) and released into a fishpond. Swaying acceleration records were integrated two times. Fluctuation of the integrated wave was very similar to one of depth. Surging acceleration fluctuated at a frequency of 4Hz in rapid start and 2Hz in moderate swimming. To understand the relation between the frequency and swimming speed, largemouth bass (FL 41.0cm, BW 0.95kg) was attached with an acceleration data logger (W190L-D2GT, Little Leonardo) and made to swim in a water tunnel. Tale beat frequency was determined analyzing swimming forms recorded by a digital video camera. The surging acceleration frequency was equal to the tale beat frequency and increased linearly with the rise in the water velocity. It seems that acceleration data have a potential to estimate swimming speed and depth of underwater animals.

CANCELED **OIV-12: Developing a continental-scale acoustic tracking array: Initial results from the census of marine life project POST**

David Welch (david.welch@kintamaresearch.org)

Others session

OIV-13: Stroking pattern in inhaling penguins and exhaling seals

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Energy efficient locomotion is particularly important for breath-holding divers because high levels of swimming activity may quickly deplete oxygen reserves, leading to the early termination of a dive. We deployed acceleration data loggers on penguins and seals to record their flipper movements and body angles, and to define the contrasting swimming patterns employed by these divers under natural conditions. The data obtained from king *Aptenodytes patagonicus* and Adélie *Pygoscelis adeliae* penguins indicate that they stroke continuously during the descent, while they stop flipper beating during the ascent and glide back to the surface. Biomechanical calculations indicate that the air volume of these birds can provide enough buoyancy for this passive ascent. According to the data obtained from adult Weddell seals *Leptonychotes weddellii*, prolonged gliding during descent was observed in thinner females, while fatter females exhibited only stroke-and-glide swimming throughout descent as well as ascent. The surface interval between dives of gliding seals was significantly shorter than that of stroking animals, suggesting that the prolonged gliding is a more efficient method of locomotion. Our results indicate that diving animals take advantage of their respective positive

(penguins) or negative (thinner seals) buoyancies for vertical transit according to their specific conditions and requirements.

OIV-14: Evaluation of swimmer's stroke skill using acceleration and gyroscope sensors

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Authors applied a sensor data logger to the stroke skill analysis in human swimming. In the competitive swimming, it is known that the upper extremities produce dominant propulsive force. Until now, we could not observe swimmer's arm rotational movement with respect to the longitudinal axis, such as pronation/supination of the forearm. Our data logger has triple accelerometers and triple gyroscopes. Like a data logger for marine animals, it is waterproofed and has a microprocessor, memory, A/D converter and battery. However, we had improved it for the human swimming analysis. The measurement range of the acceleration is more wider (Max10G) than that of sea animal versions. And the sampling rate is more higher. The logger has a digital trigger start function which could synchronize the logger and other equipment, such as an video frame counter. The logger has triple gyroscopes for the direct measurement of the swimmer's forearm tri-axial rotational movement. We will present the result of the application study of our data logger. We could quantified and qualified of the forearm movement during swimming and determine the skill level of the human swimming using data logging method. This is a innovation for the swimming coaching.

OIV-15: Telemetry and animal welfare - practical refinements

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The primary advantage of telemetry and datalogging is that interference with 'normal' behaviour and physiology can be greatly reduced, which can improve animal welfare and produce more valid and relevant data. Other possible benefits include reductions in the number of animals used in individual projects and the potential to use telemetered data to monitor health and wellbeing.
Implantation surgery and the presence of the device can both impair animal welfare, however. It is essential to ensure that any impact on animals is minimised, while maximising all the potential benefits of telemetry and datalogging. The Joint Working Group on Refinement is producing a report on refinements in telemetry that aims to help achieve this by setting out current best practice in:
* Selecting a device
* External attachment or implantation
* Anaesthesia and surgery
* Post-operative pain management
* Monitoring animal wellbeing
* Conducting field studies using wild animals
* Removing devices and releasing or rehoming animals
* Passing on information about best practice and refinements in all of the above
The poster will provide an overview of the Group's main findings and recommendations. A list of resources to assist with refinement in all of the above areas will be available.
1 British Veterinary Association Animal Welfare Foundation
2 Fund for the Replacement of Animals in Medical Experiments
3 Royal Society for the Prevention of Cruelty to Animals
4 Universities Federation for Animal Welfare

OIV-16: Previous results regarding a wild boar radiotelemetry survey using GPS collars

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The Global Positioning System (GPS) is an important new technology for spatio-temporal behaviour studies of animals. Although VHF telemetry has been substantially used, our study is the first report, to our knowledge, of the use of GPS systems to track free-ranging wild-boars. Although the need for collar larger than those used for VHF tracking, the crowded vegetation of the habitat and particular features of the social group behaviour of wild boars posed some technical difficulties, one dummy and two GPS collars were successfully attached on three adult sows. The three collars remained on the animals for over six months without causing any injury to the wild boars. Forty-one daily cycles (24 hours) as well as daily locations over 142 days could be recorded for a single animal. Detection efficiency and location recording were significantly better during the night than during the day ($t = -2.89$, $p = 0.0052$). In the light of these results, GPS technique appears to be an efficient tool to study wild boars activity. Progress in the survey of animal movements at a fine scale is of prime interest for animal management programs in order to appreciate a sustainable level of animal population regarding damage problems.

Closing session

OV-1: Reconstructing the past using futuristic developments: Trends and perspectives in logger technology in air-breathing marine animals

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Over the last two decades there has been remarkable progress in the development of sensory systems coupled with loggers that have been attached to free-living marine animals. Increases in sensor resolution, sensor diversity and memory size have been coupled with decreases in unit size. Thus, the periods over which animals have been monitored have increased from hours to years while the sampling frequency has decreased from minutes or seconds to fractions of a second. Five main interrelated trends can be identified. Determination of animal position in 3 dimensions, the characteristics of the environment in which the animals operate, animal behaviour, physiology and bio-mechanics. These are discussed and perspectives given with regard to what is expected in the future.

OV-2: Sensory ethology of odontocetes

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Sensory inputs obviously have important role to determine the behavioural response of underwater animals. Approaching predator, escaping prey species, movement of other conspecifics are detected by visual, acoustical, mechanical or chemical sensors of marine creature. However, few observation has been done on the behavioural response to the information, which gathered by the sensory systems of aquatic animals *in situ*. Odontocetes have an advantage to observe the way to use sensory systems and their underwater behaviour simultaneously. Odontocetes are known to have a highly developed acoustical sensory ability called echolocation, whose sound production is possible to be recorded by a micro-datalogger composed of high-sampling rate and large-memory size devices, lately. Observation of searching effort, target distance, jamming avoidance among conspecifics in the use of the bio-sonar as well as precise behavioural recording by micro-dataloggers is only applicable to odontocetes. Additionally, digital camera datalogger enables to identify prey species and to let us know what the

animal saw underwater. Here I will present future perspective and methodology for the research on forthcoming 'sensory ethology' using bio-logging techniques.

OV-3: The secret life of marine mammals: Electronic tags meets satellite remote sensing

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Recent advances in tag technology coupled with satellite remote sensing are providing new insights into the foraging ecology of pelagic organisms. Tag-bearing animals can be used as autonomous ocean profilers to provide oceanographic data in key oceanic regions. A significant advantage of tag collected oceanographic data is that they are collected at a scale and resolution that matches the animals behavior. Specific examples include our work on northern elephant seals and crabeater seals. These studies have detailed the movements and diving patterns with respect to such oceanographic features as frontal systems, bathymetry and ice extent. Our data indicate that male elephant seals feed in specific locations associated with marked bathymetric features, whereas females forage in areas associated with water column features such as oceanic currents and frontal systems. Our work with crabeater seals indicates that they remained deep within the pack ice throughout the winter, and were more likely to be located in shallow water where the bathymetric gradients were greatest, and in areas of higher sea ice concentration. Together these studies exemplify the value of merging satellite remote sensing data with animal behavior. However, a finer scale analysis of diving behavior can be carried out by comparison to the water column temperature structure as determined from temperature sensors on the animals.

OV-4: The behavioural ecology of marine mammals: balancing data with models

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Much of behavioural ecology concerns the investigation of trade-offs between alternative scenarios for maximising fitness. The extreme plasticity of responses by animals to different circumstances is beginning to be understood in terms of the decisions that underpin these trade-offs. The criteria used for making these decisions include the immediate and recent environmental conditions and the state of the individual, measured in terms of both the animal's physiology and its position in space. To have any hope of understanding the basis upon which decisions are made by animals, we have to be able to measure the dynamics of these environmental and biological state variables and this can be achieved by sensing and logging information. Biologging systems have resulted in remarkable progress in our knowledge of the basic biology of marine mammals and seabirds. However, I suggest that the ease with which some forms of data can now be gathered has resulted in an imbalance between data and models. Indeed, much of the current effort has not yet progressed beyond simple observation and recording and the measurement of many of the most important state variables (e.g. food availability and body condition) has received relatively little attention. The future challenge is to develop biologging systems that develop understanding by testing models of behaviour through the measurement of the appropriate environmental and biological state variables. The behavioural ecology of diving is an example where there has been significant progress; theoretical models that include state-based trade-offs have been tested using biologging systems and new systems are adding to our capabilities to test increasingly sophisticated versions of these models.

Poster presentations

Cetacean session

P-1: Whale ecology observation satellite system by means of a dedicated satellite (WEOS)

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The Whale Ecology Observation Satellite System is composed of three segments, namely (1) Ocean, (2) Space, and (3) Ground.
The ocean segment consists of plural probes attached to whales. Each probe includes several sensors, on position, pressure, temperature, etc. The probe sends the data together with the individual identification code in a telemetry wave to the satellite, when a probe surfaces at the occasion of breathing of the whale. A dynamo driven by the motion of the whale generates the electric power necessary for the instruments in the probe.
The space segment is a dedicated small satellite of 50 kg, which is on a polar orbit of 800 km high. By deploying a 3 m mast the attitude of the satellite is controlled by gravity gradient torque to keep the antenna facing to the earth. The satellite WEOS collects the telemetry signal from the probe, and stores the ecological data in the onboard memory.
The ground segment is a Tracking and Command station, and it locates at the Chiba Institute of Technology. The station sends command signal to the WEOS to retrieve the ecological data collected and stored in the satellite memory.

P-2: Tracking baleen whales: development of the e-D tag, a small, biologically inert, implantable radio tag

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Studies of at-sea movements of large cetaceans have been limited by the difficulty of reliably attaching radio tags. Here we describe the development of several versions of the e-D (electronic-Discovery) tag; a small, biologically inert, blubber-implantable radio tag. The latest version of the tag is a small (134mm x 21mm) titanium encased dart which is delivered from a crossbow, shot from a small boat.
Two Mark I e-D and one Mark II e-D tags have been successfully deployed on blue whales. The first two Mark I tags did not achieve full penetration in the blubber, and transmitted for 7 and 30 days respectively. The Mark II e-D tag achieved full penetration, but the salt water switch was slightly covered by blubber, rendering the tag inactive. After 40 days (January 13 2003) the salt water switch became exposed and until 24th January 2003 (the date of submission of this abstract) the tag has continued to provide about 7 locations each day (on a 6hr on: 6hr off duty cycle), giving a total deployment time so far of 51 days.
The tagged whales showed slight, or no responses to being struck by the tag. A Mark III e-D tag is currently in development. It will differ only slightly from the Mark II and is expected to be tested in March and April 2003. The aim of this research is to develop a reliable, easily deployed whale tracking tag that can have wide utility in cetacean research.

P-3: Diurnal pattern of diving behavior in striped dolphins, *Stenella coeruleoalba*

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Pop-up archival transmitting tags (Wildlife computers) were deployed to three wild striped dolphins using small harpoons in open sea (the east of the North Pacific Ocean). We succeeded in retrieving the tag from one dolphin after popping-up and obtained one-week length data in time series of water temperature, light level, and depth in 5 seconds intervals.
The results indicates clear diurnal pattern of diving behavior. Diving depth in the daytime was 22.6±17.5 m (mean±S.D.), whereas that in the nighttime was 126.7±120.9 m and the maximum was up to 705 m. Descent rate in nighttime was correlated with dive depth and greater than that in daytime. Surface interval after dive was correlated with dive duration in nighttime, but not in daytime. It suggested that striped dolphins mainly forage in nighttime.

P-4: Surfacing time budget of the bottlenose dolphin

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Using Argos satellite tags (TCU-150, Telonics Inc., U.S.A.), tracking of bottlenose dolphins started December 6, 2002 in Taiji, Wakayama, Japan (33° 35'N, 135° 56'E). Tags were attached to the dorsal fin. Accumulated surfacing time was reported to the satellites (software option BM970702). This option detected exposure of top of the tag to the air longer than 300ms as "surfacing". During the period of December 6-15, 2002, the average ratios of surfacing time to passed time were 4.8% (n=31, 2.4-11.9%, SD=1.7%, Argos ID#19552 for female of 286cm) and 5.4% (n=31, 2.8-27.4%, SD=4.6%, ID #20123 for male of 289cm), respectively. If the individual dolphin surfaces independently, the above ratio (approximately 5%) corresponds to the ratio of number of surfacing dolphins in a school. In principle, the actual school size could be estimated using the ratio. However, the drive fishermen in Taiji, who can confirm the actual school size by landing, usually estimate the school size as 2.5 to 3 times of observed number of dolphins at a time. Probably this discrepancy came from 1) that the dolphins surface synchronously to some extent or 2) that the drive fishermen correct the count at a time by repeated and sequential observation.

Seal session

P-5: Foraging dives of Australian sea lions: Theoretical prediction of swimming speed and predictability of target depth

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In most species of diving animals, there are few reports consistent with the model which have been predicted that the optimal travel speed to target depth rather decrease with increasing of the depth. One reason for the lack of consistency between theory and observations is that it is difficult for animals that forage well offshore to know the depth at which they can locate their prey before they dive.
We examined dive data of six adult female Australian sea lions (*Neophoca cinerea*) at Kangaroo Island in South Australia during their nursing period. Their target depth was comparatively predictable because they are bottom feeder. The results indicated that when the depth of seabed was predictable (as reflected by a small coefficient of variation for dive depth), the relationship between swimming speed and dive depth was consistent with the model. Acceleration data during dive indicated that fluttering of fore flippers and body swing were well synchronized in animals of which swimming speed was consistent with the model, but were irregular in animals in which swimming speed was not consistent with the model.

P-6: Spatial use of the Southern Ocean by juvenile southern elephant seals from Macquarie Island

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The cost of bio-logging units has often limited sample size and made annual and age group comparisons impractical. Recent demographic studies of the declining southern elephant seal population at Macquarie Island have shown that the survival of juveniles (age 1-4 years) is the most important factor influencing population size, and there is a marked reduction in survival during the third year of life. Little is known about the juvenile seals behaviour at sea and how oceanic variability may influence the probability of survival.
Using new, cheap and reliable temperature-light loggers and temperature-depth-recorders (Wildlife Computers), we tracked 50 seals during 2000-2001, over 82 individual trips to sea using geolocation.
Location data collected from the juvenile seals have been used to create spatial distribution maps that provide a first description of habitat use in the Southern Ocean. We have defined the optimal sample size and spatial resolution needed to cover the region used by the entire population of juvenile seals. The differences in spatial use between individuals and age groups, and their relationship to oceanic properties have also been analysed. These are important factors to consider in order to understand the decrease in survival during their third year of life.

P-7: Fine scale foraging interactions between Antarctic fur seals and the oceanographic features in the southern Indian Ocean

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The diving activity, foraging locations and pup provisioning behaviour of ten female Antarctic fur seals from the Kerguelen Archipelago in the southern Indian Ocean were examined in February 2000 using satellite transmitters coupled with time-depth recorders. The foraging activity of the seals was examined on a nightly basis with respect to a range of oceanographic parameters (sea surface temperature, chlorophyll distribution and bathymetry). Five seals utilsed oceanic waters (1870 m) characterised by relatively warm SST of 5.4 ºC to the north and east of the colony (ecoregion 1), whilst four of the remaining seals travelled to the south-east (ecoregion 2) to waters typical of the surface expression of the Polar Front (3.7 ºC) located over the continental shelf break (597 m). Only one seal foraged in both regions during the course of a single foraging trip. The diving behaviour of seals clearly differed between regions, with diving activity within the warmer ecoregion 1 being characterised by deep dives (55.5m), a relatively low proportion of time spent diving and high hourly vertical depths. Conversely, diving behaviour within the cooler ecoregion 2 was, on average, to shallower depths (34.5m), while proportionately more of the time was spent diving (54% cf. 47%). Despite differences in environmental conditions encountered during foraging trips and consequent changes in diving activity, the foraging efficiency of mothers, in terms of daily pup mass gain per foraging cycle, was similar in both ecoregions.

Bird session

P-8: Body heat saving in Brunnich's Guillemots during diving in cold water

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A high and stable body temperature allows endothermic animals to become effective predators in the marine ecosystem. Diving seabirds, however, are believed to extend their aerobic dive time by reducing body temperature while diving in cold water. How do diving seabirds achieve a high diving performance while reducing their physiological activities such as a lower body temperature while diving in cold water? In the present study we have used a data logger (16-mm diameter, 50-mm length, 14-g mass, Little Leonardo Ltd, Tokyo) to study free diving Brunnich's guillemots (*Uria lomvia*). At each dive, they increased the body temperature at the core region by 0.42 ºC while it decreased in the peripheral region by 0.50 ºC. These temperature changes observed during diving could be the consequence of selective blood flow to the core region. These physiological adjustments may enable guillemots to conserve body heat in organs important for effective diving and may save oxygen stored in order to extend aerobic dive time.

P-9: Peripheral heat loss adjustments in diving king penguins

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Hypothermia may be an important factor to explain outstanding apnea performance in relation to oxygen stores in several diving endotherms. One way to adjust core temperature is to control peripheral blood perfusion and heat flow. Thus, body shell is of primary concern in thermoregulatory processes. In king penguins, peripheral and internal tissues undergo important temperature falls during supported diving activity. To determine mechanisms involved in diving related hypothermia, we recorded temperature on two subcutaneous areas in foraging King penguins: the flank, covered by feathers, and the brood patch, bared and highly vascularizated.
Results showed that both tissues were strongly influenced by diving activity, (temperature drops up to 20°C). Temperature changes of both skin areas were nearly parallel in a diving bout, but in some instances, they showed an inverse tendency in their temperature evolution. Moreover, complete rewarming of both tissues after diving activity showed different kinetics. Usually, skin temperatures decreased during descents to depth. However in one third of all descents, we found periods during which the brood patch showed a slight increase in its temperature, a good argument for an active thermolysis process. Our results suggest controlled peripheral heat loss through complex adjustments of body shell perfusion.

P-10: Hypothermia in the diving king penguin: locomotor muscles are also concerned

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Remarkable reductions of abdominal temperature recently found in free-diving birds have emphasized the potential role of core hypothermia in decreasing the cost of diving. However, this hypothesis is in contrast to the classical model of diving heterothermy based on conservation of core temperature, peripheral vasoconstriction, and cooling of the peripheral body shell. To progress in this debate, we have measured in foraging king penguins the temperature changes of the main locomotor muscle, the pectoral. Results showed:
- At the scale of a dive, the most common pattern of changes in pectoral temperature was a slight increase (less than 0.6°C) during the descent and bottom phases followed by a reciprocal decrease during the ascent and the surfacing interval.
- However after several hours of continuous deep-diving, a significant decrease of pectoral temperature was achieved (up to -3.3°C).
- Temperatures of the pectoral muscle are under fine control, as the birds able to warm-up this muscle before the

end of intensive deep-diving bouts.
To sum up, in contrast to the classical model, these results suggest the occurrence of a general hypothermia that includes the most active and heat-producing tissue of the organism while diving.

P-11: Over wintering in Antarctica: not so cold for an emperor!

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Emperor penguins rely on marine resources that are far away from their breeding colonies and then have to fast on sea ice during the Antarctic winter. Huddling is the key to save energy under these drastic conditions. Outside the huddle, Emperor penguins metabolic rate is minimum from –10 to +20°C (thermo neutral zone), a temperature range in which they don't have to spend energy to maintain their body temperature constant and high. How do they take advantage from the microclimate into a huddle?
During 4 consecutive years, we recorded the temperatures surrounding the male emperor penguins in the course of their breeding cycle by using data loggers glued on their back and chest feathers.
During pairing, huddle duration varied between 4 min to 7 h (lasting for 1 h 30 min on average). Most pairing huddles occurred at night, *i.e.* only 5 % during day time, corresponding to very cold ambient temperatures independently of the wind. Surprisingly, the temperatures within 58 % of the huddles were well above 20°C (upper critical temperature) and 3 % reached 37°C (body temperature).
From pairing to the end of the incubation, emperor penguins spent 49 % of their time inside their thermo neutral zone even though mean wind-chill was -34°C. Subsequently, we assume that there was a cold induced increase in their metabolic rate for only 30 % of time.
To sum up, due to their social thermoregulatory behaviour, it is not so cold for emperor penguins to over winter in Antarctica.

P-12: Foraging strategies of chinstrap penguins at Signy Island, Antarctica: importance of benthic feeding on Antarctic Krill

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Chinstrap penguins *Pygoscelis antarctica* are one of the major consumers of Antarctic Krill *Euphausia superba* in the Southern Ocean. We studied foraging trip patterns and diving behaviour of chinstrap penguins breeding at Signy Island, Antarctica, using time-depth recorders. The diving depths of our study birds were much deeper (to 179 m) than previous studies on this species, with modal maximum dive depth at around 90 – 100 m. Diving patterns and profiles included typical pelagic dives, but also included series of consecutive square-wave shaped dives reaching similar maximum depth, the typical characteristics of benthic dives. These benthic-type dives were more abundant in diurnal foraging trips than overnight trips. Analysis of stomach contents showed that penguins on both types of trip fed almost exclusively on Antarctic krill. There was a positive relationship between indices of the proportion of benthic feeding and of foraging efficiency (stomach content mass divided by foraging trip duration). These results highlight the potential importance of benthic feeding on Antarctic krill, the first such recorded instance for chinstrap penguins. This previously undescribed foraging strategy by one of the major avian consumers of Antarctic krill provides a new insight into the predator-prey interactions of the Antarctic coastal marine ecosystem

P-13: Parental foraging effort and offspring growth in Adélie penguins: does working hard improve reproductive success?

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Studying variability of parental foraging and provisioning behaviour in relation to reproductive success is fundamental to improve understanding about regulation of reproductive effort in animals. A hypothesis that parents with higher foraging effort have higher offspring growth rates was tested in chick-provisioning Adélie penguins *Pygoscelis adeliae* in Antarctica. Time spent diving per day, an index of foraging effort, varied among male or female parents, and among pairs. These daily inter-individual or inter-pair differences in time spent diving appeared to be consistent over the 2-week study period within each breeding season. The amount of time spent diving per day by parents did not affect brood growth rates. Frequency of meals delivered by parents had a significant effect on their brood growth rate. Meal frequency was also independent of time spent diving. Body mass loss rates of breeding pairs had a positive effect on brood growth rates. Our results did not support the hypothesis that parents with higher foraging effort have higher offspring growth rates. We suggest that parental allocation of resources obtained during foraging, rather than an extent of foraging effort, is an important process determining offspring growth rates in Adélie penguins.

P-14: Foraging behavior and parental provisioning in Adélie penguins in a fast sea-ice area where feeding opportunities and sites are limited

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In order to examine how individual variation in foraging behavior affect provisioning rate in long-lived seabirds, trip duration and diving behavior were monitored in 20 pairs of Adélie penguins rearing chicks in a fast sea-ice. Their chick growth was simultaneously measured to estimate provisioning rate. They fed in small open waters, which was closed during the night because of icing. Birds making trips during the night tended to make longer trips because they lost the foraging opportunity during the night, hence they brought meals less frequently. Birds diving deeper made longer dive-bouts presumably because they fed on profitable prey, and they consequently tended to bring large meals. Thus, birds making trips in day-time and diving deeper provisioned faster. There were no significant correlation among foraging effort, body mass decrease rate and provisioning rate. These suggest that the feeding pattern rather than foraging effort affect provisioning rate.

P-15: Time allocation of provisioning Adélie penguins under delivery constraints

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In birds and mammals, parents have to adjust their foraging and provisioning within variable environments. In this study, we explain the time allocation of breeding Adélie penguins (*Pygoscelis adeliae*) during a foraging trip using an optimal provisioning model with the following two constraints: (i) penguins have to switch sequentially their foraging from self-feeding to provisioning feeding because they have to transport food for chicks in their stomach, (ii) they cannot deliver food greater than their stomach volume. The behaviour of penguins under different food availability was generally consistent with the predictions of our model. Moreover, under low food availability, the energy delivery rate was lower but the proportion change of the mass of

accumulated body tissue of adults after a trip was higher, indicating parents might keep the self-feeding dive time ratio higher than the predicted value. This is due to a risk sensitive response of parents against local food variability, which may be the causal mechanism underlying the trade-off between their own survival and reproductive effort in an uncertain foraging environment.

P-16: Diving simulation concerning Adélie penguin

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The mechanism of the diving paths for Adélie penguins has not been analyzed whether it is caused by minimum energy locomotion or minimum diving time locomotion.
An optimal control theory for flight paths of planes is used for analyzing a diving path of a penguin to investigate it. Penguins are modified an object like a rugby ball with a pair of small wings. Forces affected on swimming penguins are gravity, buoyancy, lift and drag by beating wings, and induced drag from the shedding vortices. Moreover, the mass of the fluid surrounding the body is moved by its locomotion and it is so compatible with the mass of the body that the inertia force of the fluid mass cannot be negligible. This added mass is an important factor to analyze the object affected by buoyancy. The analyzed data was compared with observed diving ones, a part of the data 97GA4715 at JARE 43 by PD2G data logger. The numerical results have relatively good agreement with the observed data. It is found that numerical calculation is very effective to grasp the diving situation such as diving posture, lift, and thrust coefficients.

P-17: Does balance count when attaching external devices to penguins?

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We tested the effect of the position of time-depth recorders (TDRs) on the balance of little penguins (*Eudyptula minor*) at the Penguin Parade ®, Phillip Island, Australia.
Initially, the TDRs were attached centrally to the lower dorsal area of the penguins' backs, as is widely suggested in the literature. In the water, the penguins showed strong signs of imbalance. They tilted from side to side trying to maintain stability, avoided diving and did not move around the pool. When the TDRs were moved forward, closer to the penguins' centre of gravity, the penguins started diving, swimming and preening as they had before having the TDRs attached. The TDRs were comparatively lighter (1.7% of the penguins' body mass) and more streamlined (3.9% of a little penguins' frontal surface) than devices used on other larger penguins.
For penguins, energy expenditure is higher when carrying even small devices. This extra energy may not only be due to 'the drag effect' but also to the penguin trying to compensate for the imbalance caused by the device. We suggest researchers should consider both drag and balance when attaching devices to aquatic species and interpreting results. The final place of attachment may be a compromise between reducing the drag effect and allowing the animal to maintain its balance.

P-18: Estimation foraging area and dive pattern of rhinoceros auklet

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The information of foraging locations is important for studying foraging ecology of wide ranging small seabirds, to whom both land and satellite based radio tracking techniques are hard to apply. We sampled the vertical

profiles of seawater temperature where Rhinoceros auklets were diving by bird-borne data loggers. We attached temperature-pressure recording loggers on nine birds rearing chicks at Teuri Island, Hokkaido in June 2002 and recovered five. Simultaneously CTD data were collected by R/V Hokuyo-maru in their potential foraging area. Most of temperature profiles experienced by birds during dive bouts were within those recorded by CTD, hence we could estimated locations where the birds were diving. Large individual variation of foraging area was observed. Auklets foraged more frequently in northern area of Teuri Island. The auklets dove deeper in 44º30' - 45º00'N than in southern and northern foraging area. This technique is effective for small diving seabirds, though response time of the sensor should be improved.

P-19: Foraging sites selection by rhinoceros auklet

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Rhinoceros auklets (*Cerorhinca monocerata*) breeding in Teuri Island, Hokkaido, change their prey seasonally and annually, which has been thought to reflect the variations in the local oceanographic conditions. We attached depth-temperature-acceleration data loggers on free-ranging rhinoceros auklets to relate the features of the waters selected for foraging to the birds' foraging strategies. Logger data delivered information on both the vertical water-temperature profiles and the foraging ranges estimated from the flight time measured by the acceleration data. The locations of the foraging areas were estimated from logger data and sea surface temperature data (from satellite image). Rhinoceros auklets used a wide range of foraging grounds and changed their foraging areas seasonally and annually but foraging site selection was not only driven by sea temperature.

P-20: Non-breeding distribution and movements of Australasian gannets

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Australasian gannets (*Morus serrator*) are a major marine predator feeding on inshore pelagic schooling fish and cephalopod species. Recent studies have demonstrated that there is considerable overlap in the prey consumption of gannets during the breeding period and fishery catches, with the impact of the fishery on gannets likely to be greater than the converse. However, knowledge of the movements and distribution of gannets outside the breeding season and the potential for competition with commercial fisheries during this period is limited. This project aims to determine the non-breeding movements and distribution of Australasian gannets using specially designed micro data loggers (a miniaturized geolocation and activity-recording device) developed for seabird research by the British Antarctic Survey. At the completion of the 2002-2003 breeding period 40 micro data loggers were attached to adult gannets (i.e. 20 male and 20 female) of known age (separated into ‘young’ and ‘old’ age categories), thereby allowing an investigation of sex and age based differences in movements and distribution of gannets during the non-breeding period. This information will be invaluable for establishing the potential for competition/overlap between gannets and commercial fisheries outside of the breeding period.

P-21: Plunging with gannets

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Gannets have one of the most spectacular prey-capture behaviors of all marine predators, plummeting from up to 30 m into the water. However, there is little detailed information on this brief behavior. We monitored the biomechanics of plunge diving in free-ranging Cape gannets (*Morus capensis*) using a rapid-sampling acceleration and depth recorder. Our data provide the first detailed description of this highly specialized foraging technique. Surprisingly, we recorded a very small impact when gannets entered the water, which can be either the results of the remarkable streamlining of this bird, or a sampling frequency too small to detect this extremely brief event. Streamlining process was initiated as late as 0.13 s before the impact. Birds use their momentum to travel underwater before actively braking once they attain the desired depth. Gannets sometimes used their wings for underwater propulsion during the course of occasional W-shaped dives. After chasing prey, birds always ascended passively back to the surface, making use of their buoyancy to complete the dive at the lowest possible cost. Finally, 2.9% of dives were initiated from the water surface, birds flapping during the underwater descent phase, indicating that gannets do not rely solely on plunge hunting.

P-22: Estimation of the diet of seabirds based on logger data

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Determining the feeding behaviour of animals is a key step in understanding the ecological processes that rules ecosystems. However, assessing the feeding activity of free-ranging individuals, especially seabirds, may prove particularly challenging. This has led researchers to rely on data recorders to estimate when, what and how much prey were captured by seabirds. Initially, timing of prey intake was estimated using undulations in depth profiles or dashes in swim speed profiles of foraging seabirds. However, this did not account for prey missed and was restricted to diving seabirds. Recently, substantial information on timing of prey intake and amount of food ingested was obtained using oesophageal temperature recorders (detection > 50% of prey ingested, ranging in size from krill to myctophids). Unfortunately, this method rely on temperature differences between prey and predators, being restricted to endotherms feeding on ectotherms. In this regard, beak movement detectors are independent of the temperature parameter. Here, beak angle and duration of beak opening are linearly related to prey mass and length. Besides detection efficiency, these loggers are non-invasive and easily deployed on seabirds. Used in combination with other data recorders, they should have various potential applications in several research fields.

P-23: A miniature day light levels data and activity related data storing recorder for tracking of animals including flying birds for periods of up to eight years at a time

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The device has a light level sensor. Periodically the ambient light level is measured and recorded. Data, once the animals return and the recorders are retrieved, are converted into latitudes and longitudes. This enables geographic positions of a recorder to be estimated twice daily.
The instrument is also configured to detect and record history of time spent in water against time flying or on land. For Sea Birds it is related to activity and behaviour.
Small size, a low profile and robust packaging is crucial for deployments on flying birds and diving animals. Long battery life is often essential (e.g. after fledging juvenile wandering albatrosses remain at sea for 5 years).
Low unit and operation costs are very desirable, together with simplicity of operation.
Dimensions of an instrument are 22*19*12mm. Weight in air is 9g. Weight in water is 4g. It is pressure tested to 700m depth of water. It can log data for up to eight years. The cost of a recorder is less than $70. User interface is very friendly.
The principles, design specification and circuit description of the device are presented, together with examples of data from field tests on Grey-headed albatrosses *Thalassarche chrysostoma* to illustrate performance.

P-24: BGDL-II - A GPS Data Logger for Birds -

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We developed a GPS data logger which consists of a GPS antenna, a GPS receiver, a timer, a memory, and a battery. It is principally designed for long period tracking of migratory birds. It has the ability to fix about 600 positions with one small lithium battery. We can set arbitrary measuring schedule using a PC connected to the equipment prior to the experiment. Thus, for example, we can track a bird over six months fixing positions three times a day. The weight is 67g including a battery and a 30m water proofed package. The main advantages of BGDL-II compared to the ARGOS system are: 1) several times cheaper equipments, 2) no charge for satellite links, 3) more than ten times smaller error in the obtained position data, and 4) larger flexibility in the schedule setting. These are realized, however, at the cost of real time delivery of the position data. We have to re-capture the bird to get the data stored in the memory. In this presentation, we explain the principle of operation, configuration, and performance of the equipment and the results of the tracking of albatrosses around Galapagos Islands.

CANCELED **P-25: A study of foraging behavior of royal albatrosses, *Diomedea epomophora*, using GPS data-loggers**

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P-26: Chick growth and parent foraging strategy of the Streaked Shearwater population breeding in the Kuroshio warmer current, Japan

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Chick growth and parent foraging performance of Streaked Shearwaters *Calonectris leucomelas* were studied on Mikura Island (33º 52’ N, 139º 14’ E), Izu Islands, Japan. Individual chicks increased body mass in zigzag pattern and showed obesity almost throughout the nestling period. They partitioned their growth energy into the two periods: the growth of skeleton and its related body part in the first half and the growth of feathers and its related body part in the second half nestling period, though it resulted in their slow growth as a whole. This growth feature in shearwater chicks contributed to avoid energy insolvency and was considered to function to loose parents from intensive provisioning to chicks throughout the nestling season. Parents tracked with PTT satellite transmitters repeatedly conducted short and long trips from chick early age, that corresponded to short trips in the warmer current around the island for six days and to long trips 500~1000 km north to the convergent waters off the northern Honshu and southern Hokkaido for a week on average. They finished their breeding season after conducting northward long trips also spending for a week on average and began southward migration to the equatorial waters.

P-27: Continuity assessment of migration route network of endangered Oriental White Storks (*Ciconia*

***boyciana*) based on analyses of satellite telemetry data**

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Oriental White Storks (*Ciconia boyciana*) migrate thousands kilometers between various wetlands in East Asia each year. They breed primarily in the Russian Far East and overwinter in southeastern China. Remnant population is about 2,500 and its IUCN Red List status is endangered. Conservation efforts for such a long distance migrants that focus only on breeding and wintering grounds can be adversely affected by migration-route scissioning due to loss of stopover habitat. From 1998 to 2000 we satellite-tracked the migration of Oriental White Storks throughout their range to identify the stopover sites that are critical to maintain migration route continuity. By analyzing satellite telemetry data in detail, we generated a potential migration route network, which enables us to simulate the effect of loss of arbitrary stopover sites on migration route continuity. The simulation result suggests that stopover sites facing Bohai Bay and Laizhou Bay in eastern China are the most critical for maintaining migration route continuity. If these critically located stopover sites were lost, the storks' wintering ground along the Yangtze River in southeastern China would be geographically isolated, most storks would not be able to complete their autumn migration, and this endangered species would be further endangered.

P-28: Fast sinking lines reduce seabird mortality in longline fisheries.

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Time-depth recorders were used to measure the sink rate of longlines in the New Zealand ling fishery. Sink rates to 15 m depth of demersal longlines with integrated weight (IW) were tested against unweighted longlines and lines with externally attached weights (6 kg/49 m) in the New Zealand ling fishery. Longlines with 0 g/m (unweighted), 25 g/m, 50 g/m 75 g/m and 100 g/m integrated weight averaged 0.11 m/s, 0.227 m/s, 0.272 m/s, 0.317 m/s and 0.353 m/s, respectively. The longline with externally attached weights sank at 0.32 m/s. IW longlines sank instantly, reaching 1 m depth in 6-9 s whereas unweighted lines took >20 s to reach this depth. IW longlines containing 50 g/m added weight are recommended for testing in a subsequent trial to examine the effectiveness of IW longlines in reducing seabird mortality in autoline longline fisheries.

P-29: Can albatrosses be cephalopod dependent?

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The deployment of satellite tracking devices (Platform Terminal Transmitters), along with the collection of food samples, were used to understand the foraging regimes and cephalopod diet of three species of albatrosses breeding at South Georgia (54°S 38°W).
The grey-headed albatross *Thalassarche chrysostoma* typically concentrate their foraging at the Antarctic Polar Frontal Zone where the ommastrephid squid *Martialia hyadesi* is the main target. In the austral summer of 2000, our satellite tracking studies showed that grey-headed albatrosses foraged mainly in Antarctic Peninsula waters, *M. hyadesi* was absent from the diet and the grey-headed breeding success was low.
For black-browed albatrosses *Thalassarche melanophrys*, although *M. hyadesi* was absent in years when breeding success was low.
The wandering albatrosses *Diomedea exulans* breeding success was very constant, foraging patterns were similar between years and their cephalopod diet was always dominated by the cranchiid *Kondakovia longimana*

(*M. hyadesi* was a rare item).
We suggest: a) grey-headed albatrosses breeding success is highly dependent on cephalopods which dominate their diet; b) black-browed albatrosses are less affected by the variation in cephalopod availability; c) wandering albatrosses can adapt to cephalopod variability between years, perhaps as a result of their large foraging range.

Reptile session

P-30: Continuous diving behavior of gravid leatherback turtle in French Guiana - When & How does she have a rest? -

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Leatherback turtle is the largest and most pelagic of extant sea turtles. Recently Eckert (2002) reported that in the US Virgin Islands gravid Leatherback turtles swim continuously, with little or no resting. Surface resting or basking must not occur. If moving long distance, turtles swim just below the surface. However, these findings raise the question how and when they have a rest. We studied the diving behavior of gravid leatherbacks in French Guiana using data loggers which records speed, depth and acceleration. Turtles usually made a series of short and shallow dives between deep dives. But we found that turtles sometime took long surface intervals without any flipper movements. Tail beat intervals during deep dives were relatively constant, but stroke-and glide phase constituted some portions of dives. Taken together, gravid leatherback turtles did not swim continuously but spent a considerable time for resting.

P-31: Satellite tracking of cultivated hawksbill turtles, *Eretmochelys imbricata*, in the Gulf of Thailand

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Migration abilities of hawksbill turtles which are cultured in captivity from a hatchling stage were examined in the Gulf of Thailand by a satellite telemetry method for the first time. Two juvenile (4 yeas old)and tow sub-adult hawksbill turtles (12 years old) were deployed with Platform Transmitter Terminals (PTTs) on their carapaces and were released from the Mannai Island in 2001. Signal data obtained showed that all hawksbills moved only along the coastline in the upper of the Gulf of Thailand near the Mannai Island within the water depth less than 20 m. The swimming speed ranges 0.45-0.57 km/hr determined on high class of location accuracy signal (LC 1-3). Juvenile hawksbills might not be able to decide to stay in any habitats in only 2-3 months, while sub-adult turtles might have more good trend for searching to feeding and resting areas.
We must get more enough data on migration of cultivated hawksbill turtles to understand how they could find out and stay at their suitable habitats in natural open sea.

P-32: Habitat utilization and migration behavior of sea turtles in the South China Sea

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Objective: Sea turtles in Asia, populations are now decreasing and all of them are endangered. However their biological behavior and migration paths are unknown in the Asian waters. Collaborative research project has begun since 1999 between Japan and ASEAN. The migration paths of post nesting adult female green turtle were focused as the first objective of research by using satellite system (PTTs).
Results: The tracking was carried out in two different nesting beaches; Kram Island, where is located in Gulf of Thailand, inner part of the South China Sea. Another was Similan Island in the Andaman Sea. In the South China Sea side, we found three different post nesting migration paths both of western course along the Malay Archipelago and eastern side of the Gulf of Thailand. Western going group arrived at Jawa Sea about 40 to 50 days. After leaving Vietnam coast, they were separated into three courses. One was arrived at Sulu Sea passing through the South China Sea, next one went toward the open sea. The turtles in the Andaman Sea went to islands in Indian. Swimming speed is closely correlated with sea grass density distribution along the coastal zone.

Fish session

P-33: *In situ* behaviour of female Chum salmon (*Oncorhynchus keta*) monitored using a newly developed data-logger

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Considerable information on the behaviour and physiology of salmon in rivers has been obtained in laboratory studies and field observations based on visual records. It is difficult to observe fish behaviour, so data collected visually are often fragmentary and from a limited area. To better estimate the behaviour of free ranging female chum salmon in rivers during the final stage of their life history, we continuously monitored females using a newly developed data-logger and video camera. The data-logger continuously recorded two-axis acceleration, depth, speed, and temperature for ca. 120 hours per salmon. After synchronizing the specific characteristic of two-axis acceleration, speed and depth profiles and video camera data, eight behavioral patterns were identified; swimming, nosing, exploratory digging, digging, probing, crouching, spawning, and covering. The time spent in each pattern was then determined. This study demonstrated the feasibility of a newly developed data-logger for estimating the behaviour of free ranging female salmon in rivers.

P-34: How fast does homing salmon swim in the ocean?

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Swimming speeds of homing salmon can be one of the keys to understand the mechanisms of a homing migration. We tagged a maturing chum salmon (fork length = 685 mm) which was considered to be of Japanese origin with a small data logger (sampling intervals of data: speed and depth = 5; temperature = 60 sec) in the Bering Sea (56º30'N, 179º00'E) on July 9, 2000. This salmon was retrieved off the Hokkaido coast of Japan 67 days after the release and data of 51 days were successfully recorded. The fish usually swam at the surface water column or just above a shallow seasonal thermocline and rarely stayed deeper than 50 m. During

the Oceanic homing migration, salmon showed a regular pattern of short diving from the surface to the thremocline with high speeds at the bottom phase of dives in the daytime. The average swimming speeds were 60 to 70 cm per sec and it suggests that the homing chum salmon moved to the coast almost straightly from the oceanic feeding ground.

P-35: Biotelemetry research on upstream migration of chum salmon in the Shibetsu River

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The restoration of river environments by reconstruction of meanders was carried out for the first time in the Shibetsu River, eastern Hokkaido, Japan. In order to clarify how channel alteration affects upstream migration of mature male chum salmon (*Oncorhynchus keta*), we investigated salmon behavioral profiles in terms of swimming depth and temperature using DT micro-dataloggers, and swimming speed by propeller micro-dataloggers, which were sutured to the anterior part of the dorsal fin. We also tracked and monitored salmon upstream migration using radio transmitters attached directly to the micro-datalogger as well as ultrasonic transmitters inserted into the stomach. These studies were carried out both before and after stream reconstruction. A temporal profile of water depth and swimming path of tracked salmon indicated that they preferred to swim near the bottom along the riverbanks, and stayed for extended periods in pools with slow water flows and vegetation covers. They also chose to use the reconstructed meandering channel at the confluence point of original stream. These results indicate that chum salmon in the Shibetsu River prefer slow current for upstream migration, and that the complicated flow conditions generated by reconstruction of stream meanders offer good habitat for upstream migrating salmon.

P-36: Relationship between salmon homing migration and phase of the moon

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Studies have previously been made on the effects of chemical and magnetic senses on salmon homing migration. Some researchers have also hypothesized that salmon use a memory of geographical features and depend on a sun-compass for migration. Both these theories rely on the salmon using visual sense. According to some results of bio-telemetry research for salmon, the diurnal rhythm of their vertical movement has been observed. They select a shallower depth in night time, while they select a deeper depth in the water during the day. Phase of the moon varies hours of moonlight and brightness on the sea surface, therefore the salmons swimming depth may also vary dependant on the phase of the moon. The swimming depth of salmon fitted with archival-tag was investigated accurately. It was found that their swimming depth during the time around full moon was shallower than during the other phases of the moon. This result suggests that the moonlight influences the orientation of salmon homing migration.

P-37: An energy-saving strategy of migrating flatfish determined with an acceleration measurement as indices of activity

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Intermittent swimming behaviour of marine fish with negative buoyancy, such as swim-glide behaviour, has been hypothesized to result in a saving of energy required for locomotion between two points. However, there have been no studies that tried to prove this hypothesis in the wild. This has been due in part to the difficulty of

observing and monitoring free-ranging fish in the open sea. Previous conventional tagging experiments have indicated that Japanese flounder, *Paralichthys olivaceus*, sometimes migrated in the far distance, recaptured 1,000 km from the point of release.
In order to measure energetic cost of free-ranging flatfish during migration, it is important to know the activity and time budgets of flatfish on its migration route. Using a depth and acceleration data-logger on Japanese flounders, we obtained continuous record of swimming speed, depth, tailbeat activity and body angle of free-ranging flounders, simultaneously.
Compared the migration cost between continuous swim and swim-glide, covering similar distance, migration by adopting swim-glide technique resulted in a 22.3% reduction in number of tailbeats. Thus, this energy-saving strategy allows flatfish with negative buoyancy to migrate the long-distance and to increase the duration of active behaviour (foraging and/or burying).

P-38: Vertical movement and behavioural characteristics of free-ranging Japanese flounder, *Paralichthys olivaceus*, in the Tsugaru Strait

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Japanese flounder, *Paralichthys olivaceus* are commercially important fishes and widely live in water around Japan. Previous study shows that they performed four behavioural pattern in wild, i.e. active swimming, burying patterns, inactive gliding, lying on the bottom. Yet there is little information about their behavioural characteristics how their activity varies over time and in relation to internal and external conditions. Thus, we monitored the behaviour of free-ranging Japanese flounder in the Tsugaru Strait using micro data-loggers. Depth and ambient temperature data were recorded for six flounders during 6-25 days. The flounders spent about 90% of time on the seabed and sometimes moved vertically off the seabed. The height, duration, ascent rate, descent rate during these vertical movements differed between day and night. Percentage of time spent off the seabed also appeared to be higher at night than in the day. This difference was presumably due to diurnal differences in behaviour, i.e. feeding in the day, migrating at night. Moreover, 95% of recorded ascent duration for each flounder was shorter than 60s. Behaviour of Japanese flounder mainly consisting of white muscle for short time swimming showed physiologically limited in natural environment.

P-39: Japan-Thai Mekong Giant Catfish Tracking Project (MCTP)

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The Mekong giant catfish (MGC) or Pla Buk in Thai, *Pangasius gigas* (Chevey), is the largest freshwater catfish in the world, and is the endemic to the Mekong basin. The biggest record was 293 kg with the total length 3 m. It is delicious and is also valuable animal protein resources for the people in the northern part of Thai. However it is a high degree endangered species. We started the Mekong giant catfish tracking project (MCTP) to investigate migration behaviors for MGC using biotelemetry by the request of the Department of Fisheries, Thai government. Tracking experiments were preliminary performed using ten rearing MGCs inserted with coded ultrasonic transmitters. Signals from the transmitters were recorded by five ultrasonic receivers which were set up within about 100-km range in the Mekong River. The signals indicated that four of the ten catfishes were passing the 60-km upward point and one catfish were passing the 40-km downward point within 9 days after the release respectively. The left 5 catfishes were not found except just after the release. We have

some plans to perform the tracking experiment in the wider ranges (several 100 km) and also the other tracking experiment in a lake.

P-40: Why does young Pacific bluefin tuna repeat dives to depths through the thermocline?

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Immature Pacific bluefin tuna *Thunnus thynnus orientalis*, marked with archival tags, were released near Tsushima Island in the East China Sea. A total of 15 fish were recovered by the following summer period and time-series data for ambient water and peritoneal cavity temperatures, recorded every 128 sec., were analyzed. Our main objectives were to investigate thermoconservation mechanisms of immature bluefin under low ambient temperature. In winter, the bluefin swam within the surface mixed layer at shallower depths during the night than during the day. On the contrary, as the thermocline developed in summer, the bluefin spent most of their time at the surface, suggesting that bluefin avoid rapid temperature change at the thermocline by making behavioral thermoregulation. During the summer, however, the fish made frequent dives through the thermocline for short periods (~640 s) during the day. As for the reason for repeated dives, the heat budget model suggests that internal heat production contributed much more than heat-transfer to the temperature fluctuation in the peritoneal cavity of bluefin and that peritoneal cavity temperature was maintained by engaging in repeat short-period dives. Long duration dives would cause a drop peritoneal temperature according to the head budget model. The purpose of this movement is considered to be feeding.

P-41: Continuous records of heart rates and swimming behavior in free-ranging fish, red sea bream *Pagrus major*, measured with micro data-logger

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In order to estimate the physiological condition and behavior simultaneously, micro data loggers were used to record electrocardiogram (ECG), speed and depth in the freely swimming fish, red sea bream *Pagrus major* in a net pen. After attaching ECG electrodes on the ventral surface, an ECG logger was attached below the abdominal surface of fish by thin string or inserted into the peritoneal cavity. Also another one to record both speed and depth was attached to the dorsal side of the fish. For about 1-5 day, depending on storage capacity of data logger, the recordings of bioelectric potential in fish heart were detectable distinctly, though the fish swam freely. Usually, the red sea bream tended to swim slowly below 1 BLs^{-1} in the net pen, however, sometimes swam rapidly at 3 BLs^{-1} or more particularly in dawn or dusk. There were no correlations between the heart rate and the swimming speed, however, an analysis of heart rate variability by means of MEM showed that high frequency components representing vagal nerve activity rose only around midnight.

Others session

CANCELED **P-42: Radio telemetry on common brazilan opossum (*Didelphis albiventris*) in urban environment**

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P-43: Behavioral analysis of domestic cats *Felis catus* using a miniaturized two-channel acceleration data

logger: preliminary reports

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For many species foraging in ecosystems that are difficult to access, e.g. wild cats *Prionailurus iriomotensis* behaviour cannot be observed directly. In this regard, animal-borne data recorders are the only mean of monitoring activity over time. Using a recently developed accelerometer, we conducted experimental trials of behavioral analysis on domestic cats. The loggers, attached on the cats collars, recorded acceleration along two axes: heaving (dorso-ventral) - swaying (right-left) and surging (head-tail) - swaying accelerations, at frequencies of 4 to 32 Hz. The cats behaviour was also filmed in order to further relate the animals activity to the output signals recorded by the logger. Behavioral observations were recorded for approximately 800 minutes. Cats'- behaviors could be sorted into 12 categories (rest, stay, feed, drink, groom, shake, roll, walk, trot, run, jump-up, and down) which were clearly detected on the logger data. Most behaviours were best determined on the surging axis, except for jumping and body postures which were best determined on the heaving axis. If heaving and surging accelerations were recorded simultaneously, the cats behaviour could be more determined successfully. Based on these preliminary results, acceleration data loggers appear to be a reliable tool to investigate the activity of terrestrial animals.

P-44: How different is the effect of buoyancy on optimal descent speed among the diving animals?

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It has been suggested that cost of transport curve shifts right up when animals descend against upward thrust of buoyancy and the speed of minimum energy requirement per unit travel distance (COT_{min} speed) increases with the buoyancy. However, the degree of the change in COT_{min} speed is different among the animals. In this study, the model that clarifies the reason why these differences exist was built up. It suggests that the effect of buoyancy on COT_{min} speed depends on the change rate of the inverse of net energy efficiency around the speed and the inverse of the efficiency is concave monotonous decrease function of swimming speed. Therefore, the effect of buoyancy decreases with increasing of COT_{min} speed. Furthermore, since COT_{min} speed of the animals that have greater resting metabolic rate is generally faster, the change of the speed caused by buoyancy is small in homoiothermal animal such as Adélie penguins (*Pygoscelis adeliae)* and large in poikilothermic animals such as green turtles (*Chelonia mydas*).

P-45: Choreography of underwater ballet in marine endotherms; Present trends and future perspectives

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Time depth recorders (TDRs) have been used extensively to document changes in depth utilization of marine endotherms over time. However, the 2 dimensional information given by these systems belies much more complex information since marine animals actually move in 3 dimensions. New systems for precise determination of movements in 3 dimensions include dead reckoners which use compasses, speed sensors, pressure transducers and body angle sensors to elucidate animal trajectory via vectors. This work presents some of the potential in these new systems, demonstrating how animal movement can be determined, how it is brought about by propulsive limb movement and how such movement can be related to prey ingestion.

P-46: Hall's contribution to monitoring animal movement or how magnets can tell when animals eat & swim

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A new technology is presented that offers insight into assessing movement and feeding activity in a variety of air-breathing marine vertebrates.
It consists of an archival unit logging data from a Hall sensor, sensing magnetic field strength produced by a rare-earth magnet, at frequencies of up to 100 Hz. Perceived magnetic field strength varies with changing distance between magnet and sensor. A magnet attached to a limb or appendage of an animal with the Hall sensor placed adjacent on the body, produces variations in the magnetic field strength perceived by the sensor during changes of limb position.
Work was focused on the positioning of the Hall sensor and on the shape and strength of the magnet with respect to the animal so as to optimise perception of limb movement. The aim was to separate feeding events from other mouth movements in the recorded data and to assess flipper stroke frequency and amplitude during locomotion.

P-47: A complete satellite telemetry system for marine mammal remote sensing

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For fifteen years the NERC Sea Mammal Research Unit (SMRU) have been leaders in the development of hardware and software to make best use of the Argos satellite system for tracking marine mammals. Current Series 9000 Satellite Relayed Data Loggers (SRDLs) are based around a low power, multiprocessor architecture with multi-channel data acquisition. The on-board Sealog software is easily customised to collect data from various sensors and for use on a range of species. Data are collected and then compressed in a variety of formats ranging from individual dive profiles to summaries. These compressed packets are then relayed via the Argos system and unpacked and stored automatically by a computer at SMRU. A snapshot of the latest data is frequently uploaded to the SMRU web site. To really 'see' the data the MAMVIS (MAMmal VISualisation) package allows the user to view it in 2D and 3D with bathymetry and other datasets such as sea surface temperature, chlorophyll concentration and ice cover overlaid. 4D datasets can be animated with the animal track. Data can also be directly imported into most popular analysis packages. Together these parts provide the most integrated system currently available for the remote sensing of marine mammals

P-48: An advance in geolocation by light

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A new analysis of twilight predicts that for observations made in narrow-band blue light, the shape of the light curve (irradiance vs. sun elevation angle) between +3 and -5 degrees (87 to 95 degrees zenith angle) has a particular rigid shape not significantly affected by cloudiness, horizon details, atmospheric refraction or atmospheric dust loading. This shape is distinctive, can be located reliably in measured data, and provides the basis for a new approach to animal geolocation.
The resulting "template fit" approach matches a theoretical model of the irradiance vs time-of-day to the relevant portion of a given day's data, adjusting parameters for latitude, longitude, and cloudiness. In favorable cases, there is only one parameter choice that will fit well, and that choice becomes the position estimate. The entire process can proceed automatically in a tag.
Theoretical estimates predict good accuracy over most of the year and most of the earth, with difficulties just on the winter side of equinox and near the equator. Polar regions are favorable whenever the sun crosses -5 to +3 elevation. Early results based on data taken on land at 48°N latitude confirm the predictions vs. season, and

show performance significantly improved over earlier threshold-based methods.

P-49: The icing of external recorders during the polar winter

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During the austral fall of 2000 seven satellite transmitters were deployed on Emperor Penguins. Five of the seven ceased transmitting from 15 to 83 days after release of the birds. These terminations were will within the expected time of transmission cessation, and much shorter than the two transmitters that either had no salt water switch (SWS) or no haul-out sensing for stopping transmissions. Based on the suspicion that there was some failure in the SWS incorporated into the five transmitters with short transmission lives, we conducted a series of experiments on semi-captive birds diving with mock transmitters of duplicate external characteristics to those used in 2000. The birds dived daily at an isolated ice hole in McMurdo Sound, Antarctica for three weeks. The mock transmitters became coated with a layer of ice that became substantial after a few days. We conclude that this layer of ice insulated the SWS so that the transmitter could not detect salt water, the signal to resume transmissions. This interpretation suggests that the use of SWS's for various programming configurations used during the winter may fail.

CANCELED **P-50: Radio telemetry on Spiny Dormouse (*Platacanthomys lasiurus*) in the Western Ghats of South India**

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P-51: Lab-on-a-chip activities developed at the Fujii laboratory: From PCR to detection system based on PDMS technology

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Recently, many applications (for example in health care or on-site measurement) require a small device able to achieve basic biochemical analysis, from the sample injection to the detection of DNA. So 20 years ago, a new concept called "lab-on-a-chip" appeared, which corresponds to the integration of all the components directly on a micro scale chip to perform an automatic analysis. The fabrication techniques are coming from the semiconductor technology, the miniaturization leads to high throughput processing, and the system integration enables the automation and parallelization.
Our research in terms of "lab-on-a-chip" are covering several aspects of the biochemical analysis, from the Polymer Chain Reaction (PCR) to the on-chip detection based on fluorescent spectroscopy, via the dielectrophoresis step to separate DNA or proteins fragments.
The microfluidic channels are designed in a silicone rubber layer called Poly (Di-Methyl Siloxane), which exhibits various interesting properties like biocompatibility, transparency, gas permeability, etc. The other advantages of this material are its low cost and easy fabrication process.
The electrodes, sensors and heaters are then deposited on the substrate (Silicon or Glass). All these devices developed separately are compatible and should be combined in order to obtain an autonomous and complete laboratory shrunk to micro scale.

P-52: Development of micro data logger to observe marine animals

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