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The distribution and photosynthetic properties of aerobic and anaerobic anoxygenic photosynthetic bacteria in the Black Sea have been characterized using Infrared Fast Repetition Rate (IRFRR) fluorometry. The aerobic photosynthetic bacteria were recently found to be ubiquitously present in the upper open ocean, and their characteristic pigment, Bacteriochlorophyll a, (BChla) represents between 0.5% to 10% of total photosynthetic pigments. These organisms are close relatives of the anaerobic purple bacteria. We hypothesized that the presence of the shallow anoxic layer in the Black Sea may create an unique environment where both aerobic and anaerobic photosynthetic bacteria are present in the water column. During a June 2001 expedition to the Black Sea, we detected the presence of BChla in the upper portion of the water column, and BChle at the top of the anoxic anoxic layer. The distribution of BChla appears to correlate with that of Chla, while BChle is only present at a very thin interface between the suboxic and anoxic zones. Such a characteristic distribution of BChle can be explained by the "sulfocline" phenomenon, where both light and H2S determine the vertical distribution of green sulfur bacteria. Additionally, the distribution of BChle may be controlled by the presence of minute concentrations of oxygen atop of the H2S layer. We describe the IRFRR signature of the aerobic and the green sulfur bacteria, quantify their concentrations in the water column, and discuss their photosynthetic competence.

OS41I-11 1125h INVITED

Unusual Radium Isotope Distributions in the Black Sea

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In Spring 2001 we conducted measurements of the radium quartet (Ra-223, Ra-224, Ra-226 and Ra-228) in the western Black Sea to be used as tracers of cross shelf transport. Samples were collected along three main transects: two over the southwest shelf to the interior basin, and one over the northwest shelf. Several surprising features in the distribution of the short-lived isotopes appeared. Radium-223 (11.4 day half life) was low throughout the sampling lines, suggesting (1) extremely slow offshore water mass transport rates or (2) minimal groundwater input along the coastlines. Unsupported Radium-224 (3.7 day half life) was lowest over the shelves, and increased with distance from shore; activities beyond the shelfbreak and into the interior basins were uniformly high. This pattern, the reverse of the normal horizontal distribution where Radium-224 is highest on the shelf and near zero beyond the slope, suggests minimal input from the coastlines and a water column source in the interior basins. Possible sources for the excess Ra-224 will be discussed, as well as implications for using these isotopes as horizontal mixing tracers in the Black Sea.

OS41I-12 1140h

Denitrification Produced ^{15}N Enrichment in the Arabian Sea: A Quantitative Assessment

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The Arabian Sea is one of the principal regions in the worlds oceans for water column denitrification, accounting for approximately a third of the total. A combination of high organic matter flux and poor intermediate water mass ventilation creates the extensive OMZ necessary for denitrification to take place. We have analyzed nine hydrographic profiles collected during the JGOFS Arabian Sea program for the $\delta^{15}N$ of NO_3^- to both estimate the isotopic fractionation factor for denitrification and to examine the influence of circulation patterns on the distribution of NO_3^- $\delta^{15}N$. Amongst other findings, maximal $\delta^{15}N$ values at depth range between 11 and 17 $^o/_{oo}$, but source waters for upwelling are more typically near 8 $^o/_{oo}$ consistent with flux-weighted averages for sediment traps.

While the isotopic fractionation factor (ϵ) varies only narrowly between stations, the actual magnitude depends on the method chosen for calculation of NO_3^- anomaly. If the N* method is used, ϵ is near 20 $^o/_{oo}$. Nevertheless, the tight relationship between NO_3^- anomaly and NO_3^- $\delta^{15}N$ allows for a more detailed $\delta^{15}N$ map to be generated based on the extensive JGOFS hydrographic data set. Taking into account associations with water masses and literature estimates for their fluxes into and out of the Arabian Sea, the influence of Arabian Sea denitrification on global marine $\delta^{15}N$ will be estimated.

OS41I-13 1155h

Isotopomer compositions of nitrous oxide in the eastern tropical North Pacific

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Nitrous oxide is an important greenhouse gas and an agent in stratospheric ozone depletion. The oceans are a major natural source of nitrous oxide; however, the reactions producing nitrous oxide in the oceans are poorly understood. We present here stable isotope and isotopomer (intramolecular distribution of ^{15}N within the linear NNO molecule) results for nitrous oxide in the eastern tropical North Pacific. Isotopomer compositions of nitrous oxide have wide variations in natural environment. Therefore, the isotopomer ratios will be very useful tool to reveal the origin and to solve the global cycle of nitrous oxide. Here we named the intramolecular sites of N_2O as $N^{\beta}N^{\alpha}O$, the middle position as alpha site and the end position as beta site. We call the mean of isotopic compositions of the two nitrogen, conventional $\delta^{15}N$, as $\delta^{15}N^{bulk}$, and "$\delta^{15}N^{\alpha}$ - $\delta^{15}N^{\beta}$" as "Site preference". The eastern tropical North Pacific (ETNP) is the significant source of nitrous oxide to the atmosphere and one of the major regions of the world ocean where denitrification occurs. The concentration of nitrous oxide reaches a maximum above the oxygen minimum zone (OMZ) and declines rapidly as oxygen becomes depleted. Therefore we expect that its source is nitrification. Below the nitrous oxide maximum we find evidence of nitrous oxide reduction, presumably by denitrification, resulting in areas where nitrous oxide is undersaturated with respect to the atmosphere. In this research, we can see relationship between the isotopomer compositions of nitrous oxide and each mechanism, nitrification and denitrification. These results can be used to analyze the other oceans data, and help to solve the mechanisms of production and decomposition of nitrous oxide. Samples were collected in The Eastern Pacific Redox Experiment (EPREX) in May-June 2000. Stations are located from the oligotrophic, oxygen-rich waters of the central North Pacific gyre near Hawaii (22.75°N, 158°W), Station ALOHA (St.1), to the highly productive, oxygen-poor waters of the Eastern Tropical North Pacific near Mexico (15°N, 98°W), Station 6. Isotopomer ratios of nitrous oxide were measured at Station 3 (16°N, 136°W) and Station 5 (16°N, 107°W). This is the first data of the isotopomer ratio of nitrous oxide in the ETNP. In this reseach, bellow the OMZ, nitrous oxide is consumed by denitrification. In this area, alpha site of nitrogen and oxygen is strongly enriched by reduction of nitrous oxide, but beta site of nitrogen is constant or slightly enriched. On the other hand, from subsurface nitrous oxide maximum to the deeper area where the concentration of nitrous oxide lower gradually, alpha site of nitrogen and oxygen is strongly enriched but beta site of nitrogen is depleted. This means that the mechanisms declining the concentration of nitrous oxide are different between two areas. This difference can be detected only by the isotopomers, but can't be detected by bulk isotope ratios.

OS41J HC: 323 A Thursday 0830h

New Insights Into the Ecology of Pelagic Animals From Applications of Electronic Tags

Presiding: **J Polovina,** NMFS, Honolulu Laboratory**; G Boehlert,** NOAA, NMFS, PFEL,

OS41J-01 0830h

Environmental Influences on Movements and Depth Distributions of Tunas and Billfishes

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Numerous studies have attempted to explain the movements and distribution of tunas and billfishes by correlating catch statistics with environmental conditions averaged over time and space. Such correlations do not necessarily elucidate the requisite relationships because the data are often not gathered simultaneously, and because error terms are too broad to demonstrate meaningful relationships. Moreover, using catch statistics to determine the effects of environmental conditions on catch statistics can never prove causation and result in tautology, unless independent measures of fish abundance are available. Other studies have correlated catch statistics with satellite-derived sea surface temperature data, but tunas and billfish do not live exclusively at the surface. More importantly, they regularly experience thermal gradients (1 C per m depth) during their rapid and repetitive vertical movements which are orders of magnitude steeper than sea surface temperature gradients (1 C per km). We suggest that sea surface temperature gradients are undetectable and are, therefore, unlikely to determine horizontal movements or aggregation. Direct observations of tunas and billfishes behaviors (collected via acoustic telemetry or electronic data-recording tags) can, however, be readily combined with information on their physiologically-based environmental tolerances, forage abundance, and appropriate satellite derived oceanographic data to provide the needed information.

We are currently combining several types of spatio-temporal scales of observational data with modeling efforts to provide key information on movements of Atlantic bluefin tuna (Thunnus thynnus). These include fine-scale foraging, searching, and travel patterns of individuals, school organization, association with environmental features in the Gulf of Maine, and large-scale movements in the North Atlantic. Our analyses utilize a Lagrangian (individual-based), spatially-explicit model of the region's bluefin tuna schooling population, and spatial analyses correlating bluefin distribution and environmental variables using simple and partial Mantel tests. This approach also provides a means of utilizing observational data to simulate time-series of regional abundance.

OS41J-02 0845h INVITED

Movements of blue whales in the eastern north pacific

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The estimated 2,134 blue whales feeding in summer off California constitute the largest remnant population of this species in the world and perhaps 25 percent of the worldwide population, yet little is known of individual foraging ranges or the stocks seasonal distribution throughout the rest of the year. Since 1993, Oregon State University has tagged 100 blue whales off central/southern California with Argos (satellite-monitored) radio tags to examine summer feeding, fall

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migration and winter habitats. Tags transmit 4 hrs/d to obtain just a few locations/d, providing conservative estimates of distances traveled and speed. Data were received up to 307 days from individual whales, with some traveling up to 16,000 km. One whale tracked 13,000 km averaged >3.6 km/h over the entire track and some had multi-month speeds >4.8 km/h. During the feeding season whales often moved quickly between high productivity coastal areas traditionally dense in krill, presumably searching for better foraging sites. During the 1998 El Niño, many blue whales were visibly emaciated. High-speed searches and large size may be adaptations to survive such events.

The fall migration south is relatively fast, not cohesive, and includes routes along the continental shelf and offshore up to 2,000 km. Whales depart southern California over several months and winter off Magdalena Bay, within the Gulf of California and west of the Costa Rica Dome upwelling, all of which are usually high in productivity. Those whales reaching Bajas southern tip, arrive in November and early December. There are some year-to-year differences in winter distribution. Many whales have winter ranges that do not overlap substantially or at all. Examination of wintering area climatologies, AVHRR and SeaWifs data strongly suggest that blue whales continue to feed throughout the winter, unlike gray and humpback whales which are known to fast. Not all whales in this stock move north into California waters during the summer, which may influence stock assessments.

OS41J-03 0900h INVITED

Foraging Behavior of Northern Elephant Seals Relative to Frontal Features in the North Pacific Ocean

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Archival data-loggers coupled with ARGOS based satellite tags are providing a detailed picture of the foraging behavior of elephant seals. They dive continuously, day and night, for the entire trip to sea that lasts between 2 to 8 months spending 90% of their time underwater, with dives averaging 20 minutes followed by surface intervals of less than 4 minutes. Modal dive depths are 300-600m with maximum dives exceeding 1500m! Male elephant seals depart Ao Nuevo rookery and travel rapidly and directly to foraging areas associated with the continental slope regions of the Aleutian Islands, Southeastern Alaska, Puget Sound and the Queen Charlotte Islands. In contrast, female elephant seals travel to foraging areas over the entire North Pacific. Our data indicate that males feed in specific locations associated with marked bathymetric features, whereas females apparently forage in areas associated with water column features such as oceanic currents or large eddies. In this study we examine the relationship between female foraging behavior and frontal systems. The behavior of female seals relative to large-scale frontal features was established by comparison of the ARGOS tracks of seals relative to satellite AVHRR images. A finer scale analysis of diving behavior relative to frontal features was carried out by correlation of dive behavior to water column temperature structure as determined from temperature sensors on the archival data loggers. Our results indicate that frontal features are an important feature in the foraging behavior of female elephant seals.

OS41J-04 0915h

Combining Electronic Tags, Environmental Data and Artificial Life Techniques to Model Behavior of Pelagic Fish in Changing Environments

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Electronic tags provide geographic positions and sometimes swimming depths of tagged pelagic fish. Simultaneous observations of the environment surrounding the tagged fish are not easy and constitute, at best, only a partial view of the local habitat of the fish. Interpretation of the fishs movement in relation to its local habitat is therefore often speculative and deriving insight into how fish utilize their local environments in the ocean is a very difficult task.

Other than static correlations between the presence of a fish in an area and some oceanic features of the same water mass (often, oceanic fronts), it is very difficult to observe the dynamic utilization of the environment by fish. On the other hand, artificial life techniques, such as neural networks and genetic algorithms, allow investigation of the dynamic relationships between fish and their environment. The general principle is that by generating simple agents capable of adaptive processes, behaviors can emerge that allow generation and evaluation of hypotheses relating to the behavioral mechanisms that allow fish to utilize their environments. Two different individual-based models are presented to illustrate this approach. The first one deals with large-scale horizontal movements of tropical tuna and the use of daily satellite sea surface temperature data. The model learns how an artificial tuna should interpret its surrounding environment each day and the results can be compared with empirical data of large-scale movements. The second model concerns small-scale vertical behavior of pelagic predators sharing the same environment. A model of the prey environment is built from acoustic surveys conducted in French Polynesia and different behaviors of predators are allowed to co-evolve to adapt to this environment. The emerged behaviors are then compared to real fishes of different species with known vertical behavior obtained from acoustic tracking experiments.

Artificial life models are especially appropriate for exploratory simulations where biologists and oceanographers look for plausible behavioral mechanisms to reproduce empirically observed fish movements and to evaluate the possible effects of changes in the environment. Ideas for future syntheses are discussed.

OS41J-05 0930h

Oceanographic Habitats and Foraging Behavior of two Sympatric North Pacific Albatrosses

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We characterized the foraging destinations and oceanic habitats of black-footed (Phoebastria nigripes) and Laysan (P. immutabilis) albatrosses breeding sympatrically at Tern Island, Hawaii. Analyses of ARGOS telemetry data in conjunction with satellite-derived sea surface temperature (AVHRR) and chlorophyll concentrations (SeaWiFS) suggest that albatross dispersion is influenced by water mass distributions over macro-mega scales (1000s km). During the brooding period (< 19 days after chicks hatched), black-footed albatrosses restricted their movements to tropical waters (> 20 o C), while Laysan albatrosses ventured into the cooler waters of the Transition Domain (15-12 o C) and the Subarctic Frontal Zone (12-10 o C). Albatross foraging ranges expanded during the rearing period (19-140 days post-hatching), when both species foraged in cooler and more productive water masses. Black-footed albatrosses commuted to the California Current, and Laysan albatrosses ventured into subarctic waters (< 10 o C) of the Gulf of Alaska, the Aleutians, and the Northwest Pacific.

We also used changes in turning and movement rates to characterize the foraging behavior of the satellite-tracked albatrosses during their provisioning trips. In particular, the negative correlation between flight speed and immersion rate suggest that slow and contorted movements are indicative of foraging behavior. The analyses of telemetry tracks revealed that albatrosses focused their foraging activities within coarse-meso scale (10s -100s km) features associated with frontal systems and continental shelves. For instance, foraging albatrosses engaged in are-restricted searching in the vicinity of continental shelves (central California Washington State, Aleutian Islands), and hydrographic fronts (North Pacific Transition Domain). Conversely, the satellite-tracked birds commuted rapidly over tropical and subtropical waters between these foraging areas and the breeding colony.

These results highlight the significance of macro-mega scale (1000s km) water mass distributions and coarse-meso scale (10s 100s km) hydrographic features to breeding albatrosses, and underscore the value of satellite telemetry to delineate the oceanic habitats of far-ranging pelagic species.

OS41J-06 0945h

Electronic Tagging of Pelagic Nekton in the Census of Marine Life

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The Census of Marine Life (CoML) is an international program with a broad mandate to examine the diversity, distribution, and abundance of marine life. Pilot projects using new and emerging technologies will help meet the CoML objectives. Electronic tagging, which provides an effective means of learning how pelagic organisms use the ocean environment, is a key element of two pilot projects presently under development. Taking a multi-species approach, the Tagging of Pacific Pelagics (TOPP) project will use a range of electronic tags to examine the distribution and behavior relative to variations in the ocean environment of the North Pacific. TOPP will use the tag-bearing animals as autonomous ocean profilers to define the oceanographic regions of critical interest. The temporal and spatial data from tags will provide an "organism-eye" view to generate a detailed understanding of how marine animals use distinct oceanic regions. Fifteen to twenty target species, ranging from bluefin tuna and northern elephant seals to albatross and marine turtles, will be monitored throughout the North Pacific. The aim is to understand animal movements and aggregations in the context of the complex and varying North Pacific environment and to provide a framework for future management and conservation of these economically and ecologically valuable resources.

The Pacific Ocean Salmon Tracking (POST) project will evaluate the hypothesis that Pacific salmon have sharply defined migration behaviors in the sea, and that salmon may shuttle between two distinct environments: their well-defined spawning grounds in freshwater, and what may be equally well-defined ocean feeding grounds. Many objectives of POST coincide with those of TOPP, but the smaller size of the target species requires use of different tagging technologies. For young salmon entering the ocean, acoustic tags and a receiver array will allow tracking individual animals over many months at sea as they move north and west along the continental shelf. Offshore, the use of archival tags will allow detailed reconstructions of the migration pathways and depths used by larger salmon in their open-ocean wanderings. The data will also demonstrate whether their foraging grounds are spatially fixed or move with changing environmental conditions. Combined, the results of TOPP and POST will provide important information on pelagic animal behavior in relation to their ocean environment.

URL: http://www.coml.org

OS41J-07 1020h

Recent Biotelemetrical Research On Salon Homing Migration

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Recent rapid advances in biotelemetrical techniques on free-swimming fish make it possible not only to monitor underwater fish movement in greater detail, but also to analyze physiological aspects of fish behavior. Three biotelemetrical instruments (ultrasonic transmitter, electromyographic radiotrasmitter, and microdatalogger) have been applied to investigate homing mechanisms in salmon, mainly lacustrine sockeye salmon (Oncorhynchus nerka) and masu salmon (O. masou) in Lake Toya, Hokkaido, Japan. These fishes offer good model systems for studying the amazing ability of salmon to migrate a long distance from open water to natal areas for spawning. By means of ultrasonic transmitters, the homing migration of mature male sockeye and masu salmon was tracked from the center of the lake to the natal areas. By means of electromyographic (EMG) radiotrasmitters (collaborative study with Dr. Jill B.K. Leonard), the energetic expense of adult migrating masu salmon was compared while fish were in the lake with when they were in the stream. By means

of micro-datalogger (collaborative study with Dr. Yasuhiko Naito), swimming depth and ambient water temperature of adult male masu salmon were recorded for a longer duration experiment. Since each technique has great advantages and/or minor disadvantages in clarifying physiological mechanisms of fish behavior, ten experts in the fields of ship engineering, signal processing, acoustic engineering, and computer science have carried out a collaborative research project to develop an automatic salmon-tracking robot boat in Lake Toya since 1999. We are trying to develop interrelated four equipment systems; 1) a robot boat, 2.5 m in length, 1.3 m in width, with a loading capacity of 120 kg, operating by two electric thrusters at 2 knots, 2) an ultrasonic tracking system detecting distance and direction of miniature pingers, 3) a signal processing and control system consisting of DGPS, acoustic signal, and gyroscope, 4) a telecommunication system between a land base and the boat. Using a NTT handy-phone circuit, we have just succeeded in tracking lacustrine sockeye salmon homing behavior by the robot boat at a distance of 100 m on October 2001. In the near future, we are planning to track salmon using the robot boat from the Bering Sea to Hokkaido.

OS41J-08 1035h

Forage and Migration Habitat of Loggerhead and Olive Ridely sea Turtles in the Central North Pacific From Satellite Telemetry

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Satellite telemetry from 26 loggerhead (Caretta caretta) and 10 olive ridley (Lepidochelys olivacea) sea turtles after capture and release from pelagic longline fishing gear provides information on their position and movement in the central North Pacific. These data together with environmental data from satellite remote sensing are used to describe the oceanic habitat used by these turtles. The results indicate that loggerheads travel westward, move seasonally north and south primarily through the region 28°- 40° N latitude, and occupy sea surface temperatures (SST) of 15° -25° C. Their dive depth distribution indicates that they spend 40% of their time at the surface and 90% of their time shallower than 40 m. Loggerheads are found in association with fronts, eddies, and geostrophic currents. Specifically, the Transition Zone Chlorophyll Front (TZCF) and the southern edge of the Kuroshio Extension Current (KEC) appear to be important forage and migration habitats for loggerheads.

In contrast, Olive ridleys are found primarily south of loggerhead habitat in the region 8°-31°N latitude, occupying warmer water with SST of 23°-28°C. They have a deeper dive pattern than loggerheads spending only 20% of their time at the surface and 50% deeper than 40 m. Three olive ridleys were of western Pacific orign while seven were hatched on eastern Pacific beaches. All 3 western Pacific Olive ridelys used migratory and forage habitat associated with major ocean currents. One olive ridley occupied the southern edge of the KEC, one olive ridley rode the North Equatorial Current (NEC) westward, and a third traveled east and west along both the Equatorial Counter Current (ECC) and NEC.

OS41J-09 1050h

Vertical movements of bigeye tuna (Thunnus obesus) associated with islands, buoys, and seamounts of the Hawaiian Archipelago from archival tagging data

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To learn more about the movement patterns of bigeye tuna (Thunnus obesus) near the Hawaiian Archipelago, we deployed archival tags on 87 fish ranging in fork length from 50 to 154 cm. Thirteen fish were recaptured and 11 archival tags returned, representing in aggregate 943 days-at-liberty. We successfully retrieved data from 10 tags, representing data from 474 days in aggregate. The largest fish recaptured with data intact was 44.5 kg (131 cm FL) and the smallest 2.8 kg (51.9 cm). The deepest descent recorded was 817 m, the coldest temperature visited 4.7 C, and minimum oxygen level reached 1 ml l^{-1}. Fish spent little time at depths where water temperatures were < 7 C and oxygen levels < 2 ml l^{-1}. Based on vertical diving behavior and geolocations, it appeared that four fish stayed immediately associated with an offshore weather data buoy where they were tagged for up to 34 days. During this time they remained primarily in the uniformed temperature surface layer (< 100 m). However, when not associated with a floating object, fish showed the "W" vertical movement patterns during the day characteristic of bigeye tuna (i.e. descending to depths below the thermocline and then returning regularly to the surface layer to warm muscles or to repay an oxygen debt). When associated with Cross Seamount, fish had vertical movement patterns similar to those of fish not associated with any structure, but that were clearly less regular. Bigeye tuna appear able to follow the movements of the deep sound scattering layer organisms (SSL) and to exploit them more effectively as a prey resource than other tuna species, such as yellowfin tuna. We also found a significant correlation between lunar illumination and average nighttime depth distribution, a behavior which mimics the movements of the SSL.

OS41J-10 1105h

The Foraging Ecology of North Atlantic Right Whales (*Eubalaena glacialis*) in the Lower Bay of Fundy

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The diving behavior of right whales (*Eubalaena glacialis*) was monitored with recoverable, suction-cup mounted, time-depth recorders (TDRs) in the lower Bay of Fundy during the summers of 2000 and 2001. The whales were tracked and the TDRs were recovered with the aid of radio and acoustic transmitters incorporated in the tag. Vertical profiles of temperature, salinity and particle abundance were collected with a conductivity-temperature-depth (CTD) instrument and an optical plankton counter (OPC) at the location of each surfacing of a tagged whale. The lower Bay of Fundy contains low zooplankton diversity and the vertical distribution of late stage *Calanus finmarchicus*, the primary prey of right whales in this area, is readily observable with the OPC. In 2000, 28 tags were deployed and of the 26 that were subsequently recovered, 31% (n = 8) remained attached for over 30 minutes and 23% (n = 6) remained attached for over one hour. In 2001, 25 tags were deployed and recovered of which 76% (n = 19) remained attached for over 30 minutes and 64% (n = 16) remained attached for over one hour. Dive characteristics and collocated environmental measurements were averaged over entire TDR deployments to achieve independent statistics for each individual right whale. Foraging right whales descended quickly (1.5-2.2 m s^{-1}) from the surface to a particular depth typically between 95 and 145 m and stayed within 2-8 m of that depth for 7-11 min before returning rapidly (1.7-2.4 m s^{-1}) to the surface. Average foraging dive depths were strongly correlated (n = 20, r = 0.918, p < 0.0001) and coincident (p > 0.05 for H_o: slope = 1 and H_o: intercept = 0) with the average depth of maximum OPC-detected *Calanus finmarchicus* abundance. Average foraging dive depths were also strongly correlated with the average depth of the bottom mixed layer (n = 20, r = 0.895, p < 0.0001), however dive depths were typically shallower than the bottom mixed layer by an average of 10 m. These results suggest that right whales forage just above the bottom mixed layer where the maximum abundance of late stage *Calanus finmarchicus* is consistently found. By directly and simultaneously measuring the physical environment, availability of prey and predator behavior, we have gained unique insights about the ecological conditions that facilitate the location and exploitation of prey by a marine apex predator.

OS41J-11 1120h

Determination of southern bluefin tuna (Thunnus maccoyii) residence time via acoustic monitoring along the south-west Australian coast

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Internally implanted acoustic tags and moored acoustic receivers were used to investigate movements of juvenile southern bluefin tuna (SBT) near Esperance, Western Australia from January to March 2001. Thirty-two juvenile SBT (mean length 66 cm) were acoustically tagged and ten receivers deployed, tested, and recovered after 38 days. The tag detection radius of receivers during validation experiments was approximately 350 meters. The receivers detected 20 of 32 (62.5%) tagged SBT during the deployment period. Tuna were detected at seven of the ten receivers and on 61.5% of days. Individual tuna were detected at a maximum of six stations, and the maximum time between tagging and the last detection event was 38 days (mean 11.5 days). There was little variation in water temperature or currents at the receivers during the deployment period, thus changes in habitat characters could not be determined or related to the tuna patterns observed. A total of 61 individual detection events lasted an average of 123 seconds; the mean interval between detection events for the same tuna was 28 hours. A mean daily residence area of 2704 km2 (circle of radius 29.3 km) was estimated for these juvenile SBT during their total detection period at the receivers.

OS41J-12 1135h

Communicating Histogram Archiving Transmitters: Insights into the Movements of Tiger Sharks

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Although there have been major recent advances in the development of electronic tags that can sample and store depth and geolocation data, researchers are still faced with the problem of actually recovering the data from the fish carrying the tag. The two most common methods are to catch the fish a second time and recover the data or to have the tag release from the fish ('pop-up') and download the data to satellite. Both methods have limitations; fish are often difficult to recapture and pop-up tags have proved unreliable in duration of attachment and reliability of reporting. We report the first successful deployment of internally implanted CHAT tags that store depth and water temperature for tiger sharks moving through their natural environments. The archived data are automatically transmitted via 'sonic modem' technology to an underwater data logger when the shark passes within approximately 500 meters of the data logger. That is, data are recovered from free swimming sharks without the need for recapture and without the need to attach the tag to the external surface of the animal. Preliminary data will be presented and the application of this technique to other species and ecosystems will be discussed

OS41J-13 1150h

Behavioral changes during tuna migration revealed by statistical analysis of tracks derived from archival tagging data

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We analyzed geolocation estimates from archival tags attached to bluefin tuna using a state space Kalman filter to estimate movement parameters, geolocation errors and most probable tracks. Estimated rates of directed movement ranged from 2 to 10 Nautical miles per day. Diffusivity estimates were around

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500 square Nmi per day. Longitude errors were approximately 0.5 degrees and latitude errors about 1.0 degrees. We applied several measures of sinuosity to analyze the estimated tracks. The distribution of sinuosity estimates indicate different behavioral modes. These results indicate that despite large uncertainties in geolocation estimates, new insights into in situ tuna behavior can be detected by detailed analysis of tracking data.

OS41J-14 1205h

Diving behavior of Pacific bluefin tuna (Thunnus thynnus orientalis) recorded by archival tags

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Immature Pacific bluefin tuna marked with archival tags were released off Tsushima Island in the East China Sea. Using time-series data on swimming depth, ambient temperature and peritoneal cavity temperature recorded by the tags retrieved, we examined the effect of ambient temperature on their dives in relation to the occurrence of feeding events. The development of their diving performance with growth was also discussed. In the East China Sea, the bluefin swam within the s urface mixed layer in winter, while as the thermocline developed in summer the bluefin spent most of the time at the surface and made in daytime repeated dives to depths through the thermocline. Further, feeding events were mostly recognized in accordance with the diving performance, suggesting that their diving is for feeding.

In summer, some bluefin migrated to the Pacific, where they made few dives in the daytime despite a deeper surface mixed layer, and they mainly made dives at dusk and dawn. This suggests that their diving patterns may possibly be affected by vertical prey distribution. The dives at dusk and dawn were supposed to be a behavioral response to temporal change in illumination since few feeding events were recognized in accordance with these dives. Additionally, diving depth and vertical swimming speed increased with growth. In conclusion, seasonal and spatial changes in the vertical thermal structure and vertical food distribution may have a great influence on the diving behavior. It is also evident that their diving performance develops with growth.

OS41K HC: 323 B Thursday 0830h

Biophysical Factors Affecting the Growth and Survival of Aquatic Organisms III

Presiding: **C Stevens,** New Zealand National Institute for Water Atmospheric Reasearch

OS41K-01 0830h INVITED

Temperature, stratification and barnacle larval settlement in two Californian sites

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The hypothesis that internal waves and bores transport planktonic larvae predicts more settlement in sites with more energetic internal motions. Barnacle settlement was monitored in five sites 20 - 100 km apart along the coast of Alta and Baja California. In five periods of observations completed between 1991 and 1996, *Chthamalus* spp., *Pollicipes polymerus*, and *Balanus glandula* settlement was consistently higher in the northern site, La Jolla, than in the southern site, La Salina. For *Chthamalus*, the most abundant settler, settlement was higher in La Jolla in 58 out of 60 paired dates, by a mean factor of 141. In 1996, time series of temperature in about 15 m of water showed that the stratification was 72% higher, on average, and that the thermocline was shallower in La Jolla than in La Salina. Consequently, internal motions of tidal and higher frequencies were more energetic and closer to the surface in La Jolla compared to La Salina, supporting the prediction of the internal bore hypothesis. The hypothesis was also supported by the result in La Jolla in that changes in settlement were positively correlated with changes in stratification. Adult barnacle density was much higher in La Jolla than in La Salina, suggesting the hypothesis that differences in stratification and settlement rate result in differences in adult density

OS41K-02 0915h

Transport of Postlarval Bivalves: Effects of Predator Activity, Sediment Grain Size, and Clam Species

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In soft bottom habitats, postlarval transport of benthic invertebrates has the potential to greatly influence patterns of recruitment. In laboratory flume experiments, the effects of a variety of factors on rates of transport of juvenile bivalves have been examined. In one experiment, the effects of sediment grain size on transport rates of juveniles of two species (*Mya arenaria* vs. *Mercenaria mercenaria*) were assessed. Rates of transport of *M. mercenaria* were greater than those of *M. arenaria*, which burrowed deeper into the sediment. Transport rates also varied with sediment grain size, being lower in coarse sediments than finer sediments for both species of clams. The potential for foraging by predators to cause disturbance, and thus to enhance transport of clams has also been examined. Transport of juvenile *M. arenaria* was increased by the presence of the seven spine bay shrimp, *Crangon septemspinosa*, but not by juveniles of the green crab, *Carcinus maenas*. Foraging *C. septemspinosa* excavate pits, disturbing the sediment surface and increasing bottom roughness. In a high flow speed treatment, ripples formed only in the presence of the shrimp. Juvenile *C. maenas* were efficient predators of *M. arenaria*, but caused less disturbance of the sediment surface and did not affect transport rates. These laboratory experiments indicate that a variety of factors will affect rates of postlarval transport of bivalves in the field. Knowledge of distances of transport also is necessary if we are to understand and predict patterns of postlarval transport. A laboratory experiment measuring transport distances of juvenile *M. arenaria* is in progress.

OS41K-03 0930h

Exchange between Embayments and the Hudson River and Implications for Zebra Mussel Populations

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The details of physical transport in rivers play a role in the spread and establishment of zebra mussel populations. Two dye studies, conducted on the Hudson River in the summers of 2000 and 2001, were designed to determine the effect of side embayments on zebra mussel transport and settlement. The dye, which was used to represent a larval cohort, was injected in the main channel near an embayment and observed over several tidal cycles. During the first study, the tides caused the dye cloud to return to the injection site over three tidal cycles. The embayment initially trapped nearly half of the dye, but runoff from a severe rainstorm flushed the dye from the embayment within a tidal cycle. These results suggest that large storms can flush larvae from embayments into the main channel, where they can settle. Measurements of larval abundance and settlement during the summer of 2000 support this conclusion.

The second study was conducted in a larger tidal bay with two, well-defined exchange locations between the bay and the main channel. Dye was injected as water started entering the bay, and a dye mass balance was evaluated by measuring dye concentrations and velocities at the two exchange sites. Visually, only a portion of the dye cloud traveled deep into the bay, while noticeable patches were trapped in dead zones near the exchange sites. These patches resulted in a large pulse out of the bay immediately after the flow direction changed. Preliminary results suggest very little of the dye re-entered the bay with the second incoming tide. These measurements allow us to estimate the fraction of a larval cohort trapped in a bay during a tidal cycle.

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OS41K-04 0945h

Isolating the Impact of Water Flow on Nutrient Uptake by Organisms Situated Within Complex Communities; An Isotope Labeling Approach

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Increased water velocity has been demonstrated to positively affect nutrient uptake kinetics at the scale of individual organisms (e.g. algae) and complex benthic communities (e.g. coral reefs and seagrass beds). However, few studies have isolated the effects of water velocity on nutrient uptake by individual organisms while they are situated within a complex community. In a series of field flume experiments conducted in a natural seagrass meadow (Thalassia testudinum), we used 15N-labeled ammonium to isolate the effects of velocity on individual components (epiphytes, seagrass, phytoplankton) of the community. The isotope label addition allowed us to determine the rate at which ammonium was removed from the water column by the entire community while measuring the rate of ammonium accumulation within the individual components.

Ammonium uptake rates for individual components and for the entire community increased significantly over a range of velocity (0.02 - 0.20 m/s) commonly observed in the field. The dependence of ammonium uptake by epiphytes and seagrass on velocity is on the order expected for mass-transfer limited uptake and suggests that water flow may control ammonium uptake by these benthic components. Furthermore, a comparison of uptake rates for seagrass leaves covered in epiphytes versus those for leaves cleaned of epiphytes indicates that epiphytes can significantly inhibit uptake of water column nutrients by seagrass leaves. Rates of ammonium uptake for phytoplankton also increased with water velocity; however, this effect appears to be indirect and a result of higher concentrations of PON in the water column with increased water flow. Results from field flume experiments conducted in other locations suggest that the effect of velocity on increased PON concentrations (and therefore uptake) is dependent on the physical and biological characteristics of the community. Results also revealed that the flow-dependent ammonium uptake by the entire community reflected the combined variable effects of velocity on uptake by individual components within the community. The application of isotope labels in field flume studies presents an effective approach for studying the effects of hydrodynamics on nutrient uptake by individual components situated within complex communities and for describing how the response of these components to water velocity relates to the overall response of the community as a whole.

OS41K-05 1020h

A Biophysical Model of Zebra Mussel Dispersal in the Illinois River

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