New modeling tools for forecasting cetacean abundance and distribution

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Species-environment models are increasingly recognized as valuable tools for assessing cetacean distributions and developing measures to reduce or avoid adverse impacts. Cetacean-habitat models can provide a finer spatial resolution than traditional abundance estimates, but model predictions are generally based on past observations rather than current or projected ocean conditions. We present and evaluate methods for near real-time and forecast models of cetacean distribution based on remotely sensed and modeled oceanographic data. Recent advancements in processing satellite-derived data (e.g., microwave/infrared blended sea surface temperature [SST] products) have virtually eliminated data loss due to cloud cover, allowing short-term forecasts based on single-day snapshots of oceanic conditions. Ocean circulation models (e.g., the Regional Ocean Modeling System, ROMS) allow medium-range forecast predictions of oceanic variables, including SST, salinity, chlorophyll, and mixed layer depth. We developed habitat models for striped dolphin (*Stenella coeruleoalba*), fin whale (*Balaenoptera physalus*), and Dall's porpoise (*Phocoenoides dalli)* using five years of line-transect survey data collected from July to November 1991-2005 in the California Current study area (1,141,800 km^2). We then incorporated daily blended SST data and monthly ROMS SST forecasts as input variables to predict species' relative abundance in 2008. Forecast ability for 2008 was assessed by the models' ranked predictions across eight biogeographic strata, as well as visual inspection of predicted and observed distributions. For all three species, the near real-time and forecast models provided enhanced ability to predict distribution patterns compared to predictions based on five-year averages. Spearman rank correlation showed a significant correlation between predictions from models using daily blended SSTs and actual survey observations ($P < 0.05$). Longer-term (3-4 month) predictive capability showed good concordance between observed sighting locations and model predictions. Cetacean-habitat models that allow forecasting of cetacean abundance on time scales of weeks or months can greatly enhance short-term decision-making and advanced mitigation planning.

The efficacy of management interventions in response to decline in relative abundance of bottlenose dolphins (*Tursiops* sp.) in Shark Bay, Western Australia

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When evaluating impacts of human activities on cetaceans, scientific research generally lacks adequate research design, spatio-temporal scale, and baseline data for comparative analysis. The current study examines changes in dolphin abundance in Shark Bay, Australia (6008 dolphin group encounters, 1988-2003) across four consecutive (4.5 y) time periods: no dolphin-watch tourism, one tour boat, two tour boats and back to one tour boat. Previously we documented a decline (14.9% per km^2) in bottlenose dolphin abundance within the tourism site compared with adjacent 36-km^2 control sites when tour operations increased from one to two (Cons Bio 2006, Bejder *et al*.). Subsequently, a ministerial decision implemented management changes allowing both licensed operators to continue their tours, but with two primary conditions: 1) only one operator was licensed to interact with dolphins within the tourism site; the second was permitted to transit through the site to interact with dolphins outside the area; and 2) GPS "black boxes" were installed on both tour-boats, which download GPS coordinates every minute to track movements. Here, we present findings on the effectiveness of this management intervention. Using the same modelling techniques as in the original study, and information from an additional ~2800 dolphin group encounters, analyses indicate a further 7.02% (95% CI=−19.1 to −2.8) decline per km^2 within the tourism site. One year of black box data showed that management intervention reduced the total amount of time tour operators spent within the tourism site. We discuss several non-exclusive hypotheses that might help explain the effects of tour-boat, other human activity and possible environmental changes on dolphin abundance over the course of the study.

U.S. Navy Integrated Comprehensive Monitoring Program

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The Integrated Comprehensive Monitoring Program (ICMP) provides an overarching framework for coordination of U.S. Navy marine species monitoring. It is intended for use as a planning tool to focus Navy monitoring priorities pursuant to ESA and MMPA requirements and as an adaptive management tool to analyze and refine monitoring and mitigation techniques over time. It has been developed in direct response to Navy Range permitting requirements established in the various MMPA Final Rules, ESA consultations, and other applicable regulations. In early 2011 the Navy established a Scientific Advisory Group (SAG) consisting of experts in marine mammal ecology, passive acoustic monitoring, and cetacean behavior. The Navy convened the SAG with the initial task of evaluating current monitoring approaches under the ICMP and existing Letters of Authorization and developing objective scientific recommendations that will serve as the basis for a Strategic Plan for Navy monitoring. The Strategic Plan will be integrated as a primary component of the ICMP and provide a comprehensive 3-5 year "vision" for Navy monitoring across geographic regions - serving as guidance for determining how to most efficiently and effectively invest the U.S. Fleet marine species monitoring budget to address ICMP objectives

and satisfy Marine Mammal Protection Act Letter of Authorization regulatory requirements for Fleet testing and training activities.

Northern Fur Seals *(Callorhinus ursinus)* of the Commander Islands: Summer Feeding Trips and Winter Migrations.

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The northern fur seal (NFS) population on the Pribilof Islands (PI) is currently declining while the population on the Commander Islands (CI) is stable. The reasons for the different population trajectories remain unknown. Comparing differences in behavioral ecology between these two populations could provide an explanation. Seventy-six lactating NFS were instrumented in 2003-2010 with time-depth recorders, sattellite and geolocation tags on the rookeries of the CI. Data were returned from 21 satellite transmitters, 29 time-depth recorders and 17 geolocation recorders. During lactation, both mean foraging trip duration and mean maximum diving depth (3.4 ± 1.3 days and 17.7 ± 6.8 m, respectively) for NFS adult females (n = 28) did not significantly change among years. Although foraging areas of NFS from the two nearby rookeries on CI overlapped, the mean directions of travel were significantly different ($p < 0.001$). The foraging patterns suggested that these females had a reliable food source that did not change despite potential environmental changes or the effects of fisheries. During their winter migration, NFS females from the CI traveled to the western part of North Pacific and stayed in the Transition Zone Chlorophyll Front (32° N-42° N, 141°E-180°E). Their winter migration routes and the location of overwinter foraging areas were positively correlated with high ocean productivity. Over 82% (n=17) of these females spent 3-8 months near the eastern coast of Hokkaido, Japan and followed the coastal high productivity areas on their way back to the CI. Lactating NFS from the PI exhibit greater summer foraging effort (longer average trip duration and bout duration; greater number of deep dives) compared with females from the CI. Probably, the difference in foraging effort could explain opposite population trajectories on the PI and CI.

HSP70 expression and antioxidant levels in feeding and fasting grey seals, *Halichoerus grypus*

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Heat shock proteins (HSPs) and antioxidant enzymes protect against intracellular protein damage, including heat, osmotic and oxidative stresses. Grey seals undergo periods of intense feeding and protracted fasting, and are an excellent starting point for investigation of natural variation in HSP protein and antioxdants in marine mammals during different physiological states. We investigated HSP70 protein expression in suckling and fasting pups, starvelings and fasting, lactating adult females. We measured glutathione, an important antioxidant in seals, and protein carbonylation, an index of oxidative damage. HSP70 was highest in muscle and heart, followed by blubber, lung and liver. Plasma HSP70 was very low. Blubber HSP70 levels were higher in suckling pups compared with all other nutritional states (ANOVA: $F_{3,22} = 3.35$, $p = 0.037$). Liver HSP70 levels were also higher in feeding pups (ANOVA: $F_{3,23} = 2.878$, $p = 0.058$), but there were no nutritional state differences in other tissue types. Glutathione levels were higher in liver (ANOVA: $F_{3,22} = 20.26$, $p < 0.001$) and blubber (ANOVA: $F_{2,17} = 6.72$, $p = 0.008$) of suckling pups compared with fasting individuals. There was no difference in protein carbonylation or oxidised: total glutathione ratio, an index of cellular oxidation state. Our data indicate greater cellular defense mechanisms in liver and blubber of suckling pups compared to other nutritional states. These pups have the capacity to prevent oxidative damage that may otherwise be induced by the large influx of fuel into the mitochondria during intense feeding, and this protection includes elevated HSP70 protein levels as well as antioxidant enzymes. High levels of HSP70 in suckling pups may also facilitate folding of nascent proteins while these animals undergo rapid protein synthesis. Understanding how these cellular defences respond to different challenges may provide insight into the susceptibility of particular marine mammal species or individuals to given stressors.

Bottom-up regulation of pelagic dolphins through resource aggregations - not biomass

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Understanding the relative roles of the biological and physical factors that control populations and communities is a central challenge in ecology and is critical for management of species and ecosystems. Trophic interactions, which in many systems determine distributions and abundances of organisms, are regulated by a combination of factors including resources and predators. In the ocean, most resources are heterogeneously distributed and highly dynamic. Using a combination of acoustical, optical, and other oceanographic techniques, we examined the relative importance of biomass and patchiness in the regulation of a pelagic marine food web involving phytoplankton, zooplankton, mesopelagic micronekton, and spinner dolphins (*Stenella longirostris*). We found that the number and intensity of aggregations, rather than total biomass, in each step of the food chain were the most significant predictors of variation in adjacent trophic levels. Phytoplankton were often found in extremely dense, thin aggregations while dense acoustic scattering layers comprised primarily of zooplanktonic copepods were identified just beneath phytoplankton layers. Layers of zooplankton were not found when phytoplankton were more diffusely distributed. The presence of zooplankton layers reduced the extent of the diel migration of mesopelagic micronekton and increased the numerical density of these micronekton. These changes in micronekton lead to increased nocturnal use of the local habitat by spinner dolphins and increases in the degree of group cooperation of foraging spinner dolphins. At all trophic levels, patches in this food chain had ecological consequences that were significantly greater than their biomass alone would predict. Our results show that resource limitation - mediated by patchiness - regulates the structure of the ecosystem and behavior of the animals in it. Because of this bottom-up regulation by patches of resources, knowledge of the aggregation characteristics of phytoplankton allows accurate prediction of the local habitat use and group behavior of spinner dolphins.