Satellite Logbook System to Remotely Capture Real-time Data to Define Billfish Population Densities and Fishing Effort Distribution: the Guatemala Billfish Sport Fishery as a Case Study

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Billfishes, particularly the Indo-Pacific sailfish (Istiophorus platypterus), remain in high densities off the Pacific coast of Central America due to environmental and ecosystem dynamic characteristics in the region. These conditions have a dual beneficial effect on billfish by inhibiting suitable volumetric habitat and increasing forage species densities that lead to high billfish catch rates. A state-of-the-art satellite logbook system has been utilized in the region to monitor the behavior of sport fishing vessels and densities of billfish species with respect to ecosystem dynamics in the region on a real-time and spatially explicit basis. This system allows the ability to hindcast and extrapolate billfish densities on a high precision spatial-temporal scale to better estimate local densities that may be susceptible to exploitation by both catch-and-release sport fisheries and commercial fisheries. Preliminary analyses show that billfish density “hot spots” correspond with strong convergence zones that fall within vessel fishing ranges. Additionally, satellite logbook data shows a significant effect of water color and primary productivity on billfish aggregations. In addition to ecosystem dynamics, satellite logbook data yields important information on the proximity of fishing vessels to one another and allows the ability to elucidate effects of crowding, density, and patchiness of fishing vessels relative to their catch rates. The long-term research on the billfish ecosystem off Guatemala offers the opportunity to define an effective habitat range and develops the unique ability to precisely assess billfishes with respect to environmental variables and fishery dynamics.

Modeling the Decision Making Behavior of Fishers in the Reef Fish Fishery on the West Coast of Florida

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The purpose of this study is to better understand and quantify the decision making process of vessels in the commercial vertical line and longline fleets that fish on the West Florida Shelf in the Gulf of Mexico. The following aspects of a fisher’s decision making process are considered: when to fish, site choice, and when to return to port. A written survey to vessel captains was administered to a sub-sample of the fleet to guide development of discrete choice models. Discrete choice models were fit using logbook data from the fishery, in conjunction with data on vessel characteristics, weather, fish price, regulations, and the price of fuel. This scenario assumes that these three decisions are made independent of one another. Results suggest that when choosing to take a fishing trip, individuals were influenced by the fishing regulations, fish price, wind speed, price of fuel, the day of the week, and vessel use frequency (continuous variable characterizing how heavily or lightly used a vessel is in the commercial fishery). When deciding to return to port vessels were influenced by the fishing regulations, wind speed, the proportion that they filled their fish hold, and the day of the week. The outputs from this modeling exercise will be used to parameterize a coupled bioeconomic simulation model used to understand the impact of fisher behavior on catch per unit of effort.
Developing a State-Space Model to Simultaneously Describe Occupancy and Abundance

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Species occurrence and the dynamics that underlie it such as local colonization and extinction are key aspects to biogeography, metapopulation biology and conservation assessments. Species abundances also play a key role in conservation assessments, predicting the risk of quasi-extinction and assessing the status of a population. When abundance data is available, information is lost when it reduced to presence / absence data in order to employ occupancy methods. On the other hand, many of the techniques used to analyze species abundances deal poorly with data that contains too many observed zeros. One way to overcome this is to employ a delta model that analyzes the zero and non-zero data differently. Such models have been commonly used in estimating cpue indices. However, it is important to separate variability in the data into that which is generated by the ecological dynamic processes and that which is generated by imperfect detectability. Here I describe a state-space delta model to do this. This model was applied to a variety of bird species with data from the North American Breeding Bird Survey.

Demography and Connectivity: Metapopulation Dynamics Guide the Design of a Marine Reserve Network

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Marine reserve networks are a potentially powerful management tool for restoring depleted populations, such as eastern oyster (*Crassostrea virginica*), however, the design of reserve networks remains unclear. Here, we integrated demographics and larval connectivity of an oyster reserve network in Pamlico Sound, NC within a metapopulation framework to determine (1) the relative contribution of each reserve to the network, thereby identifying source (*λ* > 1) and sink (*λ* < 1) reserves, (2) the potential for reserves to function as a persistent self-sustaining network (*λ* ≥ 1), (3) the network-level benefits of increasing reserve size, and (4) the optimal allocation of resources for increasing reserve size. Mark-recapture studies, fecundity analyses, and larval dispersal simulations were conducted to parameterize a spatially-explicit metapopulation model of the reserve network and assess network design scenarios. Oyster demographic rates—growth, survival, and reproduction—varied significantly among reserves, and not in the same manner, such that certain reserves could be classified as the “growers”, others the “survivors”, and yet others the “spawners”. Inter-reserve connections were rare, asymmetrical, and relatively low in magnitude (< 5%). The relative contribution of reserves to the network (*λ*) ranged from 0.6 to 15.1, indicating the presence of “source” and “sink” reserves. Over the four years of model simulations, the mean intrinsic growth rate of the reserve network (*λ*) was 0.7 ± 0.1, and thus, the network was not capable of persisting through time primarily due to limited network connectivity. Network connectivity and *λ* increased rapidly with relatively small increases in reserve size, but network persistence required an increase in cumulative network area of more than two orders of magnitude. These results suggest that while the oyster reserve network in Pamlico Sound is not currently self-sustaining, a uniform size increase of all reserves (as opposed to only sources or sinks) may be a more effective strategy to improve network connectivity, and ultimately, network persistence.
Spatial Delineation of the Benthic Community in the Northwestern Gulf of Mexico and Exploration of a Simulated Multispecies Lotka-Volterra Ecosystem

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The shrimp fishery in the northwestern Gulf of Mexico removes a large and diverse amount of bycatch every year. However, very little is known about the dynamics and interactions of the bycatch species. We utilize survey data to explore observed community dynamics of species associated with the shrimp trawl fishery and also a multispecies Lotka-Volterra to explore the mechanisms driving the community dynamics. The large-scale fishery-independent trawl surveys from the Southeast Area Monitoring and Assessment Program (SEAMAP) provide a consistent dataset to explore the dynamics of the northwestern Gulf of Mexico ecosystem and the species directly affected by the shrimp fishery. We utilized multidimensional community metrics including nonmetric multidimensional scaling and cluster analyses to examine these species community compositions spatially and temporally. Spatial and temporal trends have been identified, but temporal trends have not shown any pattern reflecting changes in shrimping effort, hypoxia, or temperature events. To better understand the temporal effects of fishing and the mechanisms of population changes on species in the northwestern Gulf of Mexico we are exploring the use of a multispecies Lotka-Volterra simulator. The Lotka-Volterra simulations allow us to examine generic species and ecosystem dynamics in response to changes in fishing pressure and environmental conditions, and to compare results with single-species assessments of the simulated data. “Gulf of Mexico-like” ecosystems are being created from hypothesized interaction rates without the full scale parameterization of other ecosystem approaches such as Ecopath. With the Lotka-Volterra model we are creating multiple baselines communities that will be used to explore specific fishing and management scenarios. Scenarios included varying levels of fishing pressure on randomly selected species, applying fishing pressure to species with similar productivity, and species which would likely have similar bycatch rates. Additionally, scenarios of fishing that transition between low fishing, high fishing and then low fishing (recovery) are also being investigated.

Effects of Bycatch Mortality on Population Dynamics in Model Food Webs

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Fisheries impact many more species than the target species alone, necessitating the use of multi-species management to account for non-target anthropogenic effects and ecological interactions. Harvest effort often decreases the abundance of non-target species through unintended effects such as habitat destruction and mortality from bycatch. However, extraction of target species can also have a positive effect on non-target species abundance by reducing competition or predation pressure. Understanding the relative positive and negative effects of harvest in a multi-species system is necessary to accurately predict changes in community dynamics and manage fisheries sustainably. I use a three-species model food web to determine the conditions under which the impact of harvest with bycatch shifts between net positive and net negative for the non-target species. The model consists of two competing prey species and one obligate predator. The results of the full model are compared with two-species competition and predator-prey models to examine the effect of bycatch on species interactions in isolation or in combination. When competition and predation are strong, harvest increases the abundance of the non-target species by lowering the numbers of both competitors and predators. The combined release from both these interactions is greater than most levels of bycatch, particularly in the three-species model. These results suggest that, when species interactions are accounted for, non-target species in highly competitive or predator-mediated systems may increase within a fishery despite moderate levels of bycatch.
Estimating Summer Flounder Mortality Rates Using Mark-Recapture Data from a Recreational Angler Tagging Program

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Managed as a single stock along the U.S. Atlantic coast, summer flounder *Paralichthys dentatus* are currently under a rebuilding plan due to large declines in abundance observed in the early 1990s. Successfully rebuilding the summer flounder population requires implementing effective management practices based on accurate stock assessments. Currently, one major source of uncertainty in the summer flounder stock assessment is the estimate of the instantaneous natural mortality rate, which is calculated using life-history based models that have not been validated for this species. We estimate a instantaneous natural mortality rate for summer flounder based on ten years of mark-recapture data collected by the Virginia Game Fish Tagging Program (VGFTP). The VGFTP relies on trained recreational anglers to tag and release popular game fishes, including summer flounder, and recreational and commercial fishers subsequently report recaptures. Over a period of 10 years (2000-2009), VGFTP participants tagged 48524 summer flounder and 558 of these fish were re-captured. Using these data, encounter and survival probabilities were estimated using a modified Barker tagging model. We also demonstrate how data from a recreational angler tagging program can be used to provide reliable estimates of mortality for stock assessments.

Estimating the Relative Abundance of Highly Migratory Bycatch Species

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The assessment and management of highly migratory species rely heavily on the catch and effort dynamics of commercial and recreational fisheries. While fishery-dependent catch-per-unit-effort (CPUE) data may capture trends in abundance, they do not represent unbiased samples of the populations; therefore, to accurately estimate relative abundance these data must be standardized to account for factors that may have impacted CPUE but are not related to changes in abundance (i.e., changes in fishing practices). These considerations are particularly important for bycatch species (e.g., sharks and billfishes) that are not directly targeted by fisheries. For these species, there may be occasional mismatches between the distribution of fishing effort and the distribution of bycatch species. Two commonly applied methods for standardizing CPUE include generalized linear models (GLMs), which can account for changes in fishing practices in a straightforward linear fashion, and habitat-based standardizations which use a nonlinear framework to directly relate the distribution of fishing effort to the species distribution. Here, we evaluate the accuracy of these methods by simulating catch data following the general effort dynamics of the Japanese longline fishery in the Atlantic Ocean and a range of assumptions regarding population trajectories and catchability by habitat for bycatch species.
A Life History Simulator to Assess the Robustness of the Salmon Stock Assessment

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Stock assessments are widely applied throughout fisheries management and are vital for evaluating the status of stocks and projecting the future catch of a stock. Regardless of the model utilized for the assessment, assumptions about the life history parameters, structure and population dynamics of the stock are necessary since many of the biological processes are not directly observable (e.g., natural mortality rates). Disparity between the assumptions made in the stock assessment tool and the true dynamics of the stock may give rise to inaccurate assessment results, which influence harvest policy and determine the future status of the stock. I use a life history simulator for Pacific salmon (Oncorhynchus spp.), to test the robustness of stock assessment tools to these assumptions. Results using a cohort reconstruction for the assessment indicate that assumptions made about size dependence of the natural mortality rate influence the accuracy of the assessment results. Additionally, the quantity and type of data available for the assessment can greatly influence the results. The use of this simulator and the data it generates has a wide potential to applications beyond assessments. For instance, using this simulator in conjunction with other modeling techniques, such as state dependent life history theory, allows us to investigate optimal life history trajectories and growth strategies for Pacific salmon under a variety of conditions and to predict how various strategies within a cohort will influence population dynamics.
Understanding the Influence of a Variable Ocean Environment on Chinook Salmon Population Dynamics

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The translation of processes influencing oceanic productivity to fluctuations in age-structured populations requires knowledge of temporal and spatial variability patterns in both population vital rates and environmental signals. Understanding these relationships makes it possible to examine specific mechanisms of how age-structured populations respond to a variable environment. Pacific salmon populations face many threats to their persistence in riparian ecosystems, yet salmon also spend a substantial fraction of their life in the ocean and environmental conditions when salmon enter the ocean play an important role in cohort survival. However, exactly how environmental forcing interacts with population dynamic mechanisms to produce fluctuations remains unclear. My research aims to improve our understanding of the spatial and temporal scales of variability in vital rates of Chinook salmon (Oncorhynchus tshawytscha) in the northeast Pacific and how they relate to local and basin scale measures of coastal ocean condition, as well as, to explore how environmental variability might influence age-structured population dynamics of Chinook salmon. I will present initial analyses of spatial and temporal patterns of vital rates from coded-wire-tagged Chinook salmon released from hatcheries from California to Southeast Alaska, and, possibly, some comparisons of Chinook salmon survival with seabird fledgling rates from coastal California.

Spatial Modeling of Yellowtail Flounder Population Dynamics

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Many marine species exhibit complex spatial structure resulting from dispersal between sub-populations, yet most stock assessment models still assume closed population structure. Ignoring the spatial complexities of sub-population structure or mixing between them can impact not only assessment results, but can be highly detrimental to proper and successful fisheries management for the entire stock complex. In recent years, major advances have been made to include complex spatial structure within stock assessments through the development of tag-integrated models. These models allow for sub-populations with movement between them. A tag-recapture data-set is used as an input data source that is included directly within the objective function of the assessment model in order to help inform movement estimates. We are currently developing such a model for yellowtail flounder off of New England, which includes three distinct stocks each with its own catch-at-age, surveys, and vital rate data and incorporates information from the yellowtail flounder cooperative tagging program. However, tag-integrated models often ignore the spatial complexities of recruitment processes and the impact of larval drift on yearclass strength, thereby excluding a key component of the lifecycle of marine species. Future work involves incorporating Individual-Based Model estimates of larval mixing rates directly within the objective function by treating larval IBM particles in a similar way to a tagged fish. As the trend towards fine scale spatial management continues, it is important that spatially structured assessment models keep pace or risk not being able to support management decisions with appropriate assessment information.
Incorporating Genetic Data into a Population Assessment for Pelagic Sharks

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Short fin mako and common thresher sharks are both targeted in commercial, artisanal, and commercial fisheries throughout the Pacific Ocean. Despite their prevalence in global fisheries, very little is known about the population biology of these two species. In this study we have developed 11 microsatellite markers for makos and eight for threshers to be used along with five previously developed for makos and three for threshers. The genetic data generated in this study are being used in kinship analysis to determine parent-offspring relationships. The parentage assignment will then be used in a mark-recapture framework to estimate population size in the Southern California Bight.

Assessing Spiny Dogfish Migration and Population Dynamics in the Northwest Atlantic

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Regional fluctuations in spiny dogfish, Squalus acanthias, abundance in the Northwest Atlantic are thought to result from variations in the migratory patterns of juvenile and mature dogfish rather than locally driven population dynamics. However, the complex spatial behavior of spiny dogfish complicates deciphering the driver(s) of population fluxes. To elucidate the underlying mechanisms of spiny dogfish migratory behavior two approaches have been undertaken: (1) delineating the distribution of the species by stage and sex and investigating habitat preferences via Cumulative Distribution Functions (CDFs) and (2) modeling the occurrence and presence of spiny dogfish using Generalized Additive Models (GAMs). Models will utilize data from the Northeast Fisheries Science Center (NEFSC) Bottom Trawl Survey conducted in spring (1968-2009) and fall (1963-2009). Analysis of habitat preference will focus on temperature, salinity, depth, and latitude for each season. The variations in abundance with time (year and Julian day) and environment (depth, bottom temperature and zenith) will be investigated by GAM modeling for the following: (1) the probability of capturing dogfish based on presence/absence data and (2) dogfish presence based on positive abundance for each season. Preliminary results indicate different habitat preferences for the various stages examined with some stages exhibiting significantly different distributions from others. Preliminary GAM results for the presence/absence of fall-captured mature females (Dev exp = 31.8%) indicate the importance of Julian day and depth, a result which is further supported by Boosted Regression Tree analysis. The probability of capture is higher at shallow depths and increases as the season progresses. For presence only of fall-captured mature females (Dev exp = 37.4%), bottom temperature, Julian day and depth were important influences on distribution. When present, mature females are most abundant around 15°C and in shallow depths. Upon completion of this project, our results will help decipher trends in abundance from changes in decadal and seasonal distributions of spiny dogfish. Differential habitat preferences and distributions between sexes within seasons have important implications regarding their evolutionary fitness and availability to the fishery.
Population Dynamics Fellows—Abstracts

Agent-based Model Evaluation of Methods to Estimate Annual Abundance for Shoaling Fishes such as Pacific Rockfish

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Pacific rockfish (*Sebastes* spp.) and other marine fishes exhibit habitat-selective and shoaling behaviors, and these behaviors may lead to imprecision or bias when estimating an annual index of stock abundance using survey data. Existing index methods of index standardization can account for either habitat expansion/contraction or shoaling behaviors, but these effects have not been combined previously in a single analysis method. In this study, we develop a spatial agent-based model for rockfish that includes habitat-selective and shoaling behaviors and use it to test a novel method combining shoaling and habitat expansion/contraction in a single index standardization. The agent-based model generates survey data that are similar to those observed for Pacific rockfish in existing trawl surveys, and can be explored for a variety of spatial and shoaling behaviors. We then use this model to evaluate the performance of a new method that uses mixture distribution methods to account for shoaling and solitary individuals and delta methods to account for range expansion. This method is compared with conventional delta-GLM models and a quantile regression delta model. The mixture distribution method decreases the estimation error of relative indices of abundance by nearly 30% when shoaling behaviors are present, without increasing estimation error when shoaling is absent. This decrease in estimation error for a relative index given fish shoals also results in a 20% improvement in the ability to estimate the slope of a loglinear model fitted to the estimated index, signifying a substantial improvement in estimating trends in abundance. The quantile regression method has lower estimation error than conventional delta models in the presence of shoals, but this error is increased by spatial effects that have little effect on other models. These simulations represent the first evaluation of mixture distribution methods for index standardization, and show that these methods could represent a substantial improvement over current methods for shoaling species such as Pacific rockfish.

Spatial Dynamics in Fisheries Stock Assessment

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Stock assessment models help managers make decisions by characterizing the population dynamics of a marine species using biological and fishery information. Most models, however, lack an explicit description of the spatial distribution of fishing activity; harvester effort is assumed to be homogeneous across the fish stock. In most cases this assumption is violated because marine species tend to congregate in favorable habitats, where they are followed by the harvesters. This research aims to describe the spatial distribution of fishing effort and identify the consequences of violating the homogeneous effort assumption. The US sea scallop fishery, the most valuable fishery in the United States in recent years, is used as a case study. A framework for this project is presented and the following major topics are introduced: (1) simulating the dynamics of the US scallop population and scallop fishery; (2) predicting the spatial distribution of the fishing fleet; and (3) determining the consequences of spatial heterogeneity of fishing to stock assessment. Progress on components (1) and (2) are presented and the implications of this project to management are discussed.
Informal Institutions, Threat of Appropriation and Resource Outcomes in the Commons

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Common-pool renewable resources (e.g., fisheries, groundwater basins, grazing lands) suffer from the inability to effectively exclude users. As a result, these resources are often utilized at a rate in excess of that which is needed to achieve the goals of sustainability or economic efficiency. This failure is institutional in nature; therefore, institutional reform in the form of strong property rights is often promoted as the most effective solution. In recent years, however, researchers have considered ways in which resource users self-organize and develop rules governing resource access, often completely removed from any formal authority. While these "rule reforms" are not always successful in achieving efficiency and/or sustainable exploitation of resources, the general consensus from the literature is that outcomes in the presence of rule reforms are at least as good as outcomes in a purely competitive industry structure - and usually better. In this paper, we consider a specific rule reform referred to as "first in time, first in right," characterized by resource users "claiming" specific spatial areas for use. We show that this type of system can lead to categorically worse outcomes at low stock levels. The conceptual analysis is framed in the context of the Georgia, USA blue crab fishery. We suggest that, in some cases, efficiency objectives might be better served by codifying informal rules into a legally binding framework.

Firm Boundaries with Impure Public Goods

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Catch shares represent large changes in the access rights to use marine resources. I will discuss how alternative access privileges affect the organization of firms in the fishing industry, such as the decision to merge or not with other firms, and how these choices further influence their environmental footprint. I apply a model of firm boundaries to the case of a common pool resource and evaluate firms’ optimal choices under different management regimes. The model predicts that reducing externalities between firms (e.g., by shifting from common-pool to catch share regulations) will influence ex ante performance investments, leading to mergers or collective ownership. The framework is extended to a "relational contract" setting where the size of the externality determines the informal agreements that can be sustained through repeated interactions. I provide supporting evidence from a quasi-experiment in the New England fishing industry where some groups called "sectors" were given collective rights to a quota share. I estimate time-varying, firm-specific productivity parameters to capture changes in firm performance. Sector participation lead to improved performance relative to similar independent fishing boats, even after controlling for selection and vessel fixed effects. Patterns of specialization and harvest composition also changed dramatically within sectors, suggesting potentially large unintended ecological consequences associated with multi-product firms after a shift in property rights and firm structure.
An Adaptive Agent-based Model of Gulf of Maine Fisheries

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Managing human exploitation of ecosystem resources involves predicting and controlling the behavior of human agents as they adapt to social, economic, and ecological changes. The 'model' of that adaptation – whether implicit or explicit – often contributes significantly to management success. An ongoing NSF-sponsored project at the University of Maine is investigating machine learning techniques to create adaptive agent-based models of the human use of fisheries in the Gulf of Maine (GOM). An existing model of the GOM lobster fishery was modified and its data and design evaluated for potential insights into the two complex systems' interactions and for design improvements required to create a more general framework facilitating adaptation to other fisheries. This talk will briefly present the design and results to date from that lobster model, the plan for developing a new model framework within which to more easily incorporate models of the sea urchin and groundfish fisheries, and initial work on collecting data for the two additional fisheries.

An Investigation into Economic Incentives Using Data from Two License Buybacks

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The rehabilitation of stock and reinvigoration of the fishery is a pervasive objective in fishery management. In order to do so efficiently the economic incentives driving fishermen's choices must be understood. Very often, commercial fishermen are assumed to be strict profit maximizers. In recent license buybacks within Maryland and Virginia, fishermen with unused licenses participated at levels much lower and with bids much higher than supported by simple profit maximization. This feeds into the long-standing identification of fishery exit inertia within the economic literature. We provide a deeper understanding of the economic incentives driving fisherman behavior, thus contributing towards the formulation of efficient stock rehabilitation policy. The data and model within this paper provide a novel investigation into how fishing licenses are valued, and represent an investigation into long run entry and exit decisions to an extent not previously possible. By combining data from the buyback process with individual fishermen catch records and a survey we administered to license holders that captures demographic and attitudinal information, we are able to demonstrate the components of utility that drive participation decisions within license buybacks. Ultimately this research could help inform future buybacks and will provide a more complex representation of fishermen's economic decision-making than has been previously presented.