Fisheries Bycatch
Global Issues and Creative Solutions
Program and Abstracts
May 13–16, 2014
Anchorage, Alaska, USA
After the symposium, please fill out the evaluation survey at surveymonkey.com/s/fisheries-bycatch
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U.S. Fish and Wildlife Service

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Overview

The registration desk will be open from 6:00 to 8:00 pm on Monday, May 12, and at 7:00 am on Tuesday, May 13, at the Hilton Anchorage Hotel, for name badge and symposium materials pick-up. Presentations will begin on Tuesday morning.

A light breakfast buffet will be available from 7:00 to 8:00 am Tuesday-Friday. On Tuesday evening an appetizer buffet will be served from 6:00 to 9:00 pm during the poster session. All other meals are on your own.

Oral presentations and posters on Fisheries Bycatch: Global Issues and Creative Solutions will be presented in the following sessions:

Session 1: Fisheries bycatch—biological and ecological issues
Session 2: Economic and social considerations of bycatch
Session 3: Accounting for bycatch of nontarget fish species
Session 4: Solutions for monitoring protected and endangered species
Session 5: Gear developments and other technological solutions
Session 6: Fishery regulatory approaches and solutions
Session 7: Industry initiatives, solutions, and cooperative research

Event To Be Held During the Symposium

Tuesday, May 13, 6–9:00 pm. Reception and poster session, Hilton Anchorage Hotel, with appetizers and cash bar. Sponsored by the North Pacific Fisheries Research Foundation.
Invited Speakers
The following experts will give invited talks at the symposium.

Keynote: Global Perspectives on Fisheries Bycatch: The Legacy of Lee Alverson
Steven Murawski, Peter R. Betzer Endowed Chair of Biological Oceanography, University of South Florida

Bycatch, Discards, and Selective Fishing: Biological and Ecological Effects and Their Impact on Fisheries (Session 1)
Shijie Zhou, Australia CSIRO

Bycatch Management in Fisheries—Impacts and Challenges (Session 2)
Gordon Gislason, GSGislason & Associates Ltd.

Bycatch in the Gulf of Mexico Shrimp Fishery (Session 3)
James Nance, NOAA Fisheries

Big Brother Is Watching… (Session 4)
Lotte Kindt-Larsen, Danish Technical University

Review of Fishing Technology to Reduce Bycatch in Asia (Session 5)
Heui-Chun An, Korea National Fisheries Research and Development Institute

The Right Bycatch Management Tool for the Right Problem: How Catch Shares and Incentive Programs Are Being Utilized and How We Can Do Better (Session 6)
Alan Haynie, NOAA Fisheries

Developing Effective Solutions to Bycatch in Alaska through Cooperative Research: Gear Modifications to Reduce Pacific Halibut Bycatch in Sole and Cod Fisheries of the Bering Sea and Gulf of Alaska (Session 7)
John Gauvin, Alaska Seafood Cooperative
Invited Speaker Biographies

Steven Murawski, Keynote Speaker

Steven A. Murawski is professor and the St. Petersburg Partnership–Peter Betzer Endowed Chair of Biological Oceanography at the University of South Florida in St. Petersburg. He is a fishery biologist with 38 years of professional experience. Dr. Murawski worked at NOAA for 35 years, where he retired as the Director of Scientific Programs and Chief Science Advisor for the National Marine Fisheries Service. In the Gulf of Mexico region he has been actively involved in assessing the environmental impacts of the Deepwater Horizon oil spill, and its implications for fisheries. Murawski is principal investigator for the Center for Integrated Modeling and Analysis of Gulf Ecosystems (C-IMAGE) funded through the Gulf of Mexico Research Initiative. He and his graduate students also assess the status of fishery stocks in the Gulf of Mexico, with emphasis on reef fish stocks. This includes a program to develop new technologies focusing on remote sensing applications for assessing reef fishes. Murawski is a USA delegate to the International Council for the Exploration of the Seas, and recently served as vice-president of ICES. He is a member of the National Academy of Science's Ocean Studies Board.

Shijie Zhou, Invited Speaker

Shijie Zhou is a principal research scientist at Marine and Atmospheric Research, CSIRO, Australia. Early in his career, Shijie was interested in fish biology and behavior when he was a lecturer at Xiamen University in China. He received a PhD in fisheries from the University of Alaska Fairbanks, and worked on crab biology, fisheries, and gear technology with the State of Alaska. He became a biometrician with the State of Oregon working on salmon stock assessment and data analyses. During the same period he was a member of the Chinook Technical Committee of the Pacific Salmon Commission, and a member of the Scientific and Statistical Commissitter of the Pacific Fishery Management Council. His research interests include stock assessment, ecological risk assessment, bycatch and discards, methods for data-poor species, Bayesian modeling, and fisheries management. He has published more than 50 peer-reviewed journal papers and a similar number of scientific reports, and is an editor for ICES Journal of Marine Science.
Gordon Gislason, Invited Speaker
Gordon Gislason is a consulting statistician and economist with 40 years experience analyzing fisheries—capture, aquaculture, processing, recreational—and energy, mining, and resource-based tourism sectors. He has written extensively on fisheries catch shares, allocation, and catch monitoring policy initiatives and their linkages. In particular, he has identified the crucial importance of comprehensive catch monitoring of landings plus discards to meeting the sustainability test and to instilling public confidence in fisheries management. Gislason also has served as an expert witness in a variety of fisheries compensation legal cases.

James Nance, Invited Speaker
James Nance currently serves as the acting director at the NOAA Fisheries Southeast Fisheries Science Center's Galveston Laboratory in Galveston, Texas. He received his PhD from Texas A&M University and has been at the Galveston Laboratory for more than 30 years. Throughout his career his research interests have been focused on the southeast shrimp fisheries, particularly in the Gulf of Mexico. Areas of research have involved shrimp fishery management, population dynamics, fishery effort modeling, and bycatch estimation. He has served as a member of the Gulf of Mexico Fishery Management Council's Shrimp SSC since the late 1980s.

Lotte Kindt-Larsen, Invited Speaker
Lotte Kindt-Larsen is PhD student at the Danish Technical University (DTU Aqua). She is mainly working on projects related to fisheries and marine mammal interactions. Much of her work has been on the implementation of CCTV cameras onboard commercial fishing vessels, monitoring bycatch of marine mammals and discards of cod. Further, she has worked on behavioral studies of porpoises in relation to acoustic alarms, development of new sounds, habituation, and habitat exclusion. Currently she is finishing up her PhD on management of fisheries in harbor porpoise protected areas.
Heui-Chun An, Invited Speaker

Heui-Chun An is a senior researcher in the Fisheries Engineering Division of the National Fisheries Research and Development Institute in Gangwon-Do, Korea, where he has conducted research since 1986. He earned his PhD in fisheries science from Pukyong National University. His current projects include developing an LED fishing light, developing biodegradable fishing material, and engineering an integrated multi-trophic aquaculture system. He was a visiting scientist at the NOAA Alaska Fisheries Science Center in Seattle in 2005-2006, and has co-convened fisheries bycatch and technology meetings for the North Pacific Marine Science Organization (PICES) and International Council for the Exploration of the Sea (ICES).

Alan Haynie, Invited Speaker

Alan Haynie is an economist at the NOAA Fisheries Alaska Fisheries Science Center. Haynie has analyzed bycatch management measures and fleet behavior in various fisheries including the Bering Sea pollock and the BSAI (Bering Sea Aleutian Islands) Amendment 80 fisheries. His work on bycatch involves the design and evaluation of bycatch reduction incentives, understanding the impacts of individual and common pool bycatch quotas on fisher behavior, and the assessment of dynamic and fixed bycatch closure effectiveness. Haynie oversees the spatial economics toolbox for fisheries (FishSET), a NOAA Fisheries initiative to improve the spatial modeling of fisheries. He has loved seafood since before he could walk.

John Gauvin, Invited Speaker

John Gauvin has an MS in resource economics from the University of Rhode Island and is currently the fisheries science director for the Alaska Seafood Cooperative. Over the last 25 years he has worked in fisheries management as a fishery economist, and completed various consulting contracts with NOAA Fisheries, regional fishery management councils, FAO, and the Organisation for Economic Co-operation and Development (OECD). Since 1997, Gauvin has focused on cooperative research to develop solutions to environmental issues such as gear modifications to reduce bycatch, and revamping flatfish trawls to reduce seafloor habitat effects. This work has involved extensive collaborations with scientists at the NOAA Alaska Fisheries Science Center and universities, and with fishing captains and vessel owners. Gauvin also serves on the board of directors of the North Pacific Research Board and is president of the Marine Conservation Alliance.
Monday, May 12, 2014

6:00-8:00 PM  SYMPOSIUM REGISTRATION AT HILTON HOTEL

Tuesday, May 13, 2014

7:00–8:00 AM  REGISTRATION AND LIGHT BREAKFAST

8:00–8:15 AM
Welcome by Paula Cullenberg and Gordon Kruse

8:15–9:00 AM  KEYNOTE ADDRESS
Global Perspectives on Fisheries Bycatch: The Legacy of Lee Alverson
Steve Murawski, University of South Florida

SESSION 1: FISHERIES BYCATCH—BIOLOGICAL AND ECOLOGICAL ISSUES
Session Chair: Chris Siddon

9:00–9:30 AM
Invited Talk: Bycatch, Discards, and Selective Fishing: Biological and Ecological Effects and Their Impact on Fisheries
Shijie Zhou, Australia CSIRO

9:30–9:50 AM
The Biological Consequences of Bycatch Measures on Salmon and Pollock
Jim Ianelli, NOAA Fisheries

9:50–10:10 AM  BREAK

10:10–10:30 AM
Fisheries Release Mortality: Knowledge and Research Gaps
Lee R. Benaka, NOAA Fisheries

10:30–10:50 AM
Implications of Bycatch, Wastage, Post-Release Survival and Size-Limits on MSY- and SPR-based Reference Points in the Pacific Halibut Fishery
Steven Martell, International Pacific Halibut Commission
10:50–11:10 AM
Escape Gaps in African Basket Traps Reduce Bycatch and Increase Body Sizes and Incomes in Heavily Fished Kenyan Reef Lagoons
E.K. Mbaru, Kenyan Marine and Fisheries Research Institute ........................................ 22

11:10–11:30 AM
Change, Evolution and Revolution: Shaping the Fisheries of the Future
Martin Hall, Inter-American Tropical Tuna Commission ........................................... 23

11:30 AM-1:00 PM  LUNCH

SESSION 2: ECONOMIC AND SOCIAL CONSIDERATIONS OF BYCATCH
Session Chairs: Gordon Gislason and Paula Cullenberg

1:00-1:30 PM
Invited Talk: Bycatch Management in Fisheries—Impacts and Challenges
Gordon Gislason, GSGislason & Associates Ltd ...................................................... 24

1:30-1:50 PM
Bycatches in Artisanal Fisheries in Developing Countries: Challenges, and Approaches to Solutions
Martin Hall, Inter-American Tropical Tuna Commission ........................................... 25

1:50-2:10 PM
The Price of Bycatch: Examining the Economic Value of Discards in US Fisheries
Sara Young, Oceana (Amanda Keledjian presenter) ................................................ 26

2:10-2:30 PM
Estimating the Economic Impacts of Bycatch in US Commercial Fisheries
Lee R. Benaka, NOAA Fisheries ................................................................. 27

2:30-2:50 PM
A Broader Perspective Would Allow for More Informed Social Debate around Fishery Bycatch Issues
Brett Molony, Western Australia Department of Fisheries .................................... 28

2:50-3:10 PM  BREAK
3:10-3:30 PM
Likely Economic Impacts under the CFP Landings Obligation and the Challenges That Lie Ahead
John Anderson, Sea Fish Industry Authority (Gordon Gislason presenter) .......................... 29

3:30-3:50 PM
Cap-and-Trade Bycatch Management with Costly Avoidance and Stock Uncertainty
Rajesh Singh, Iowa State University (Quinn Weninger presenter) ..................................... 30

SESSION 3: ACCOUNTING FOR BYCATCH OF NONTARGET FISH SPECIES
Session Chairs: Gordon Kruse and Steve Murawski

3:50-4:20 PM
Invited Talk: Bycatch in the Gulf of Mexico Shrimp Fishery
James M. Nance, NOAA Fisheries .................................................. 31

4:20-4:40 PM
Highlights from the First Update to the National Bycatch Report
Lee R. Benaka, NOAA Fisheries .................................................. 32

4:40-5:00 PM
Comprehensive Analysis of Statistical Precision of US Bycatch Estimates: Persistent Uncertainty and Future Priorities
Amanda Keledjian, Oceana .................................................. 33

5:00-6:00 PM
POSTER SETUP

6:00–9:00 PM
RECEPTION AND POSTERS AT HILTON HOTEL
Sponsored by the North Pacific Fisheries Research Foundation
Wednesday, May 14, 2014

7:00–8:00 AM  REGISTRATION AND LIGHT BREAKFAST

8:00–8:10 AM  Announcements

SESSION 3: ACCOUNTING FOR BYCATCH OF NONTARGET FISH SPECIES (CONTINUED)  
   Session Chairs: Gordon Kruse and Steve Murawski

8:10–8:30 AM  The Risk-Matrix Approach to Evaluating Fisheries Bycatch
   Craig H. Faunce, NOAA Fisheries ......................................................... 34

8:30–8:50 AM  Assessment of Cumulative Fishing Effects on Sustainability of Bycatch Species
   Shijie Zhou, Australia CSIRO ................................................................. 35

8:50–9:10 AM  Bycatch Accounting and Management in the Ross Sea Toothfish Fishery
   Steve Parker, New Zealand National Institute of Water and Atmospheric Research .... 36

9:10–9:30 AM  Portside Bycatch Sampling and Comparative Sampling of the Atlantic Herring (*Clupea harengus*) Fishery
   James Becker, Maine Department of Marine Resources .............................. 37

9:30–9:50 AM  Evaluation of Design-Based Estimators in Federal Groundfish Fisheries off Alaska
   Jennifer Cahalan, Pacific States Marine Fisheries Commission .................. 38

9:50–10:10 AM  Opportunities for Bycatch Assessment Using Electronic Monitoring
   Howard I. McElderry, Archipelago Marine Research Ltd. .......................... 39

10:10–10:30 AM  BREAK
10:30–10:50 AM
Survivability of Recompressed Barotraumatized Groundfish Bycatch in the Maine Lobster Fishery
   Jocelyn Runnebaum, University of Maine ...................................................... 40

10:50–11:10 AM
Longline-Caught Skate (Rajidae) Injuries and Handling: Prelude to Mortality Estimation
   Daniel B. Michrowski, University of Alaska Fairbanks ..................................... 41

11:10–11:30 AM
Evaluating the Flexibility of a Reflex Action Mortality Predictor to Determine Bycatch Mortality Rates
   Noëlle Yochum, Oregon State University ............................................................. 42

11:30–11:50 AM
Mortality Rates of Tanner Crab (Chionoecetes bairdi) Bycatch Discarded by Alaska Bottom Trawlers
   Craig S. Rose, FishNext Research ................................................................. 43

11:50 AM–1:30 pm LUNCH

SESSION 4: SOLUTIONS FOR MONITORING PROTECTED AND ENDANGERED SPECIES
   Session Chair: Gordon Kruse

1:30–2:00 PM
Invited Talk: Big Brother Is Watching…
   Lotte Kindt-Larsen, Danish Technical University .............................................. 44

2:00–2:20 PM
Data Management Technology for Monitoring Bycatch in International Fisheries: A Case Study
   Amos Barkai, Olrac SPS (Bonnie Hyler presenter) ............................................. 45

2:20–2:40 PM
Overlap of North Pacific Albatrosses with the U.S. West Coast Groundfish and Shrimp Fisheries
   Troy J. Guy, Washington Sea Grant ............................................................... 46
2:40–3:00 PM  
Using Avoidance to Minimize Depredation on Alaska’s Longline Fisheries  
*Jan Straley, University of Alaska Southeast (Russ Andrews presenter)*  

3:00–3:20 PM  
BREAK

SESSION 5: GEAR DEVELOPMENTS AND OTHER TECHNOLOGICAL SOLUTIONS  
*Session Chairs: Heui-Chun An and Carrie Eischens*

3:20–3:50 PM  
Invited Talk: Review of Fishing Technology to Reduce Bycatch in Asia  
*Heui-Chun An, Korea National Fisheries Research and Development Institute*  

3:50–4:10 PM  
Study on the Juvenile and Trash Fish Excluder Devices (JTEDs) in the Philippines  
*Ronnie O. Romero, Philippines National Fisheries Research and Development Institute*  

4:10–4:30 PM  
Bycatch Reduction Devices: Development, Adoption and Implementation?  
*Christopher W. Glass, University of New Hampshire*  

4:30–4:50 PM  
Environmentally Friendly Fishing Gear with Bio Resin for Reducing Ghost Fishing and Bycatch of Nontarget Species  
*Seonghun Kim, Korea National Fisheries Research and Development Institute*  

4:50–5:10 PM  
Inspiring Innovation by Capitalizing Creativity  
*Michael Osmond, World Wildlife Fund*
Thursday, May 15, 2014

7:00–8:00 AM
REGISTRATION AND LIGHT BREAKFAST

8:30–8:10 AM
Announcements

SESSION 5: GEAR DEVELOPMENTS AND OTHER TECHNOLOGICAL SOLUTIONS (CONTINUED)
Session Chairs: Heui-Chun An and Carrie Eischens

8:10–8:30 AM
Reducing Bycatch of the Japanese Snow Crab (Chionoecetes opilio)
Using Simple Modified Gears in the Danish Seine Fishery
Kazuhiro Sadayasu, Fisheries Research Agency ........................................ 53

8:30–8:50 AM
Reducing Bycatch in New England’s Groundfish Sectors:
The Development of a Fishing Area Selectivity Tool
Jonathon M. Peros, Gulf of Maine Research Institute (Riley Young Morse presenter)........... 54

8:50–9:10 AM
Systematic Approach to Minimize Discards in Gulf of Maine Shrimp Trawls
Pingguo He, University of Massachusetts Dartmouth ........................................ 55

9:10–9:30 AM
Every Halibut Counts—Two Approaches to Reducing Bycatch Mortality on Charter Boats
Terry Johnson, University of Alaska Fairbanks........................................ 56

9:30–9:50 AM
Capture Environmental Conditions of Pteroplatytrygon violacea in Waters near Gilbert Islands
Liming Song, Shanghai Ocean University........................................ 57

9:50–10:10 AM
BREAK

10:10–10:30 AM
Innovative Camera Applications for Electronic Monitoring
Farron Wallace, NOAA Fisheries ........................................ 58
<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Speaker/Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:50–11:10 AM</td>
<td>The ISSF Skipper Workshops: Working with Fishers to Reduce Bycatch in Tuna Purse Seine Fisheries</td>
<td>Jefferson Murua, International Seafood Sustainability Foundation (Gala Moreno presenter)</td>
</tr>
<tr>
<td>11:10–11:30 AM</td>
<td>Best Practice Seabird Bycatch Mitigation for Pelagic Longline Fisheries Targeting Tuna and Related Species</td>
<td>Edward F. Melvin, University of Washington</td>
</tr>
<tr>
<td>11:30 –11:50 AM</td>
<td>Illumination of Gillnets Reduces Sea Turtle Bycatch</td>
<td>John H. Wang, University of Hawaii</td>
</tr>
<tr>
<td>11:50 AM–1:20 PM</td>
<td>LUNCH</td>
<td></td>
</tr>
<tr>
<td>1:20–1:40 PM</td>
<td>Can We Be as Clever as a Sperm Whale? Efficacy of Countermeasures to Reduce Sperm Whale Depredation on Demersal Longlines in the Gulf of Alaska</td>
<td>Lauren Wild, Sitka Sound Science Center</td>
</tr>
<tr>
<td>1:40–2:10 PM</td>
<td>Invited Talk: The Right Bycatch Management Tool for the Right Problem: How Catch Shares and Incentive Programs Are Being Utilized and How We Can Do Better</td>
<td>Alan Haynie, NOAA Fisheries</td>
</tr>
<tr>
<td>2:10–2:30 PM</td>
<td>Bycatch Avoidance under Amendment 80 in the BSAI Non-Pollock Groundfish Trawl Fishery</td>
<td>Matthew Reimer, University of Alaska Anchorage</td>
</tr>
</tbody>
</table>
2:30–2:50 PM
The Importance of Location and Timing of Fishing Effort for Bycatch Avoidance in the BSAI Non-Pollock Groundfish Trawl Fishery
Joshua K. Abbott, Arizona State University .......................................................... 66

2:50–3:10 PM BREAK

3:10–3:30 PM
Proactive Management and Reactive Regulations: Accounting for Bycatch in the US Sea Scallop Fishery
Catherine E. O’Keefe, University of Massachusetts ............................................. 67

3:30–3:50 PM
Management Approaches to Improve Target Catches under Reduced Pacific Halibut Bycatch Limits
Jane DiCosimo, North Pacific Fishery Management Council .............................. 68

3:50–4:10 PM
Evaluating Common Pools to Mitigate Shutdown and Market Risk in Fishing Quota Markets with Stochastic Bycatch
Christopher M. Anderson, University of Washington ........................................... 69

4:10–4:30 PM
The Past Two Years of Catch Shares in the West Coast Groundfish Fishery: Effort Shifts and Changes in Bycatch Rates
Peter Kuriyama, University of Washington .......................................................... 70

4:30–4:50 PM
Implementation of a New Bycatch Law (N° 20.625) in Chile
Luis Cucas, Chile Undersecretariat for Fisheries and Aquaculture ........................ 71

4:50–5:10 PM [CANCELED]
Pacific Halibut Bycatch in the North Pacific: A Perspective on 36 Years
Gregg H. Williams, International Pacific Halibut Commission .......................... 72
Friday, May 16, 2014

7:00–8:00 AM  REGISTRATION AND LIGHT BREAKFAST

8:00–8:10 AM  Announcements

SESSION 7: INDUSTRY INITIATIVES, SOLUTIONS, AND COOPERATIVE RESEARCH  
Session Chair: Craig Rose

8:10–8:40 AM  Invited Talk: Developing Effective Solutions to Bycatch in Alaska through Cooperative Research: Gear Modifications to Reduce Pacific Halibut Bycatch in Sole and Cod Fisheries of the Bering Sea and Gulf of Alaska  
John Gauvin, Alaska Seafood Cooperative ........................................... 73

8:40–9:00 AM  Significant Reductions in Mortality of Threatened Seabirds in a South Africa Trawl Fishery  
Bronwyn A. Maree, BirdLife South Africa ........................................... 74

9:00–9:20 AM  Developing a Salmon Excluder for the Pollock Fishery  
John Gruver, North Pacific Fisheries Research Foundation and United Catcher Boats Association ................................................................. 75

9:20–9:40 AM  Testing of Two Industry-Designed BRDs to Reduce Pacific Halibut Bycatch  
Mark J.M. Lomeli, Pacific States Marine Fisheries Commission ......................... 76

9:40–10:00 AM  Reducing Unobserved Crab Mortality from Bering Sea Bottom Trawling Through Cooperative Research  
Carwyn F. Hammond, NOAA Fisheries .................................................. 77

10:00–10:20 AM  BREAK
10:20–10:40 AM
Excess Fish Exclusion Device: Passive System Releases Fish at Depth during Trawling
Melanie Underwood, University of Bergen ..................................................... 78

10:40–11:00 AM
Using GIS Data in Real Time to Avoid Bycatch
Dave Fraser, IMARIBA West ................................................................. 79

11:00–11:20 AM
Improving Fishery Performance in Line with Best Practice for Bycatch and ETP Species Through MSC Certification
Stephanie Good, Marine Stewardship Council ........................................ 80

11:20–11:40 AM
The Development and Deployment of a Real-Time Electronic Bycatch Reporting Solution for the Northeast US Scallop Fleet
Amos Barkai, Olrac-SPS (Bonnie Hyler presenter) .................................... 81

11:40 AM–12:10 PM
Wrap-up
Steve Murawski, University of South Florida
Keynote: Global Perspectives on Fisheries Bycatch: The Legacy of Lee Alverson

Steven A. Murawski
University of South Florida, St. Petersburg, FL, USA, smurawski@usf.edu

Fisheries bycatch—the intended or unintended catch of non-target species—is one of the most controversial and emotional issues confronted in fisheries management today. While bycatch issues and some studies date to the beginning decade of the 20th century, it wasn't until 1994 that Lee Alverson published his landmark paper “A Global Assessment of Fisheries Bycatch and Discards,” which established that over a quarter of global fisheries catch was discarded at sea. The reaction to the paper was a clarion call to overhaul the assessment of bycatch and its reduction through management measures. In the ensuing two decades, legislative, regulatory, and scientific programs have focused on the antecedents of bycatch, its effects and reduction. Perspectives from ecology, economics, and social sciences are intertwined in this process. Today all major fisheries regulatory venues have bycatch management as one of their central tenets because fisheries are generally managed on a single-stock basis to their overfishing limits. Major programs exist regionally, nationally, and globally to document, mitigate, and manage bycatch. The development of new, cost-effective technologies to monitor bycatch has allowed innovative cap-and-trade programs for bycatch management. Nevertheless, there remain significant holes in our understanding of the behavior of animals, unobservable mortalities, and other ecological and economic factors that limit our ability to manage bycatch approaching insignificance. Building upon the legacy of Lee Alverson, innovative solutions to the bycatch conundrum demand collaborative industry-agency partnerships and integration of the traditional scientific domains of technology, biology, and social science.
Invited Talk: Bycatch, Discards, and Selective Fishing: Biological and Ecological Effects and Their Impact on Fisheries
Shijie Zhou
CSIRO, Brisbane, Australia, shijie.zhou@csiro.au

Bycatch and discards are commonly seen as wasting resources, endangering vulnerable species, impairing sustainability, and causing biological and ecological damage to the environment. Unfortunately, in many cases the true biological, ecological, and fisheries consequences of bycatch and discarding are unknown. Bycatch and discards result from technological, economic, cultural, and regulatory selections. A review of limited studies suggests that the effects of selective fishing and its consequential bycatch and discards may have a range of unintended effects. The undesirable effects include modifying food web and ecosystem structure, alternating energy flow and species interactions, reducing system resilience and fisheries production, and inducing phenotypic and genotypic changes. Indiscriminately reducing bycatch through highly selective fishing may neither minimize biological and ecological effects nor support sustainable fisheries. Rather, spreading a moderate fishing pressure proportionally over a wide range of ecological components may better fulfill the goals of ecosystem approach to fisheries.
The Biological Consequences of Bycatch Measures on Salmon and Pollock

Jim Ianelli and Diana Stram
North Pacific Fishery Management Council, Anchorage, AK, USA,
jim.ianelli@noaa.gov, Diana.Stram@noaa.gov

Management measures to minimize bycatch of salmon species in the North Pacific groundfish fisheries have developed iteratively over time in response to changing oceanographic and fishery conditions. Whereas federally managed Alaska groundfish fisheries are often lauded as being highly successful from a conservation and fishery sustainability perspective, the measures to minimize bycatch to the extent practicable remains a challenge both in developing appropriate regulations and in evaluating the effect of current and alternative management systems. Here we present work that evaluates the impact of the Chinook salmon bycatch by the eastern Bering Sea pollock fishery on Chinook stocks based on the extensive sampling by observers and genetic stock identification work. Trade-offs in sampling effort devoted toward collecting more genetics information are weighed against decreases in biological data collections (e.g., on length and sex composition of the bycatch). We contrast the salmon impacts with the consequences for the current constraints on pollock fishing and how these activities may have impacted pollock catches and subsequent stock condition. Results show that starting in 2012, the abundant 2008 year class of pollock appears to be much smaller than average in the fishery. The extent that this is due to population-level density-dependent effects is contrasted with the possibility that the pollock fleet has moved from traditional fishing grounds (which may have higher Chinook salmon bycatch rates) to areas where smaller and younger pollock are available.
Recreational and commercial fisheries face continued effort restrictions due to excessive fishing mortality and slow stock rebuilding processes. Discards occur in almost all fisheries, and fishermen and scientists have sought solutions to the related issues of barotrauma and release mortality in recent years. Fishermen and managers are wondering whether long-standing release mortality assumptions used for fisheries stock assessments should be re-examined if more fish released or discarded in recreational and commercial fisheries are likely to survive. However, managers and stock assessment scientists face several data gaps in determining how various release mortality rates affect stock status and fishing levels.

In March 2013, NMFS began a process to develop a white paper to review release mortality initiatives by region; identify, prioritize, and try to resolve data gaps; and identify components of a national post-release mortality science strategy. The development process for this white paper included a September 2013 workshop of scientists from within and outside of NMFS, which was designed to provide background information. This talk will present results from the workshop and the resulting white paper, including high-priority knowledge and research gaps identified at the workshop. These gaps included:

- Quantification of unaccounted escape mortality.
- Longer-term impacts of venting and descending devices.
- Determination of effects of sublethal capture and repeated capture.
- Measurement of release mortality in fishery conditions (as opposed to lab conditions).
- Development of reliable and robust proxies for mortality.
- Effective communication regarding how discard mortality estimates are created, used, and impact stock assessments.
The current harvest policy for the Pacific halibut fishery uses a 32-inch minimum size-limit in the directed commercial fishery, and total annual catches in each of the 8 regulatory areas are based on area-specific exploitation rates. In nondirected fisheries retention of halibut is restricted. The current assumption is that 84% of the sub-legal halibut released from the directed halibut fishery (wastage) survive each year, and this rate is the same for all sizes of fish. Post-release survival rates from other bycatch fisheries are gear dependent and partially based on observer accounts of halibut release condition. This paper examines the sensitivity of estimates of MSY and spawning-biomass-per-recruit-based reference points to the assumptions of post release survival and the cumulative effects of size-selective fishing. A joint probability model for surviving the capture process is developed for modeling the instantaneous rates of retention and discarding in directed and bycatch fisheries, as well as the cumulative effects of size-selective mortality. Evaluation of the current minimum size-limit and post-release survival rates, and alternatives, for MSY-based reference points is based on assumptions about an underlying stock-recruitment relationship. The trade-offs between post-release survival, size-limits, bycatch and fishing intensity are examined from a long-term equilibrium perspective using isoclines that describe per recruit changes in spawning biomass, yield, discard, and mean weight of the landed catch.
Escape Gaps in African Basket Traps Reduce Bycatch and Increase Body Sizes and Incomes in Heavily Fished Kenyan Reef Lagoons

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There is increasing effort to develop fishing methods that increase sustainability of the fishery and reduce bycatch without sacrificing the incomes of fishers. Consequently, we explored the use of modified African basket traps (experimental traps) retrofitted with 2 cm x 30 cm, 3 cm x 30 cm, 4 cm x 30 cm, 6 cm x 30 cm, and 8 cm x 30 cm escape gaps and compared their catches with those from unmodified traps lacking these gaps (controls). Studies were undertaken in heavily fished Kenyan coral reef lagoons dominated by sand, sea grass, and coral reef. Of the 2,500 fish captured, we distinguished over 80 species from 33 families with significant differences in catch composition between the two trap types. Among the bycatch, numbers of butterfly fish and other low value species were reduced in the experimental traps. Overall, at the trap level, there were no significant differences in terms of mean length, weight, and value of the target species. Nevertheless, fish captured in experimental traps were 30% longer and 47% heavier and a decline in the capture of low value species accounted for the lack of difference at the whole trap level. Due to a strong size-price relationship in this fishery, there was a 22% increase in the economic value of the gated compared to control traps.
Change, Evolution, and Revolution: Shaping the Fisheries of the Future

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Over the years, changes in attitude and approach to the bycatch issue have resulted in many successful programs, and in the development of models of response. Formulas for success are frequently simple, but not quick or cheap. The recurring basic components are: incentives, data to understand the problem, cooperation in the researchers-fishing community to develop the solutions, and implementation through sensible management.

Bycatch mitigation programs are frequently driven by charismatic species, and the ecosystem approach is lost. If the solution is specific (e.g., tori lines, backdown), then that preference doesn’t translate in poor ecological choices. But if the solution has a generic impact (changes in hook type, mesh size, fishing depth, etc.) managers must make some difficult choices. We have yet to understand how to make these assessments in a solid ecological way. The evolution of bycatch management must include not only the evolution of the gear and procedures used to catch the fish, but also the evolution of the ecological thinking that would allow us to make wise choices, and of the management system that should sometimes produce outcomes counter to public preferences. Ecological science is also evolving, and the golden goal of the selective fishery is being challenged.

But we are missing the revolution—the development of alternative ways of capturing fish. In the past, our techniques killed a number of individuals and then we decided which ones to keep; in the fisheries of the future, we should capture alive, and only kill what we mean to keep.
Invited Talk: Bycatch Management in Fisheries—Impacts and Challenges
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Bycatch limitation is a cornerstone of modern fisheries management and a necessary condition for demonstrating sustainability. Initiatives to address bycatch can affect industry economics through the allocation or access to fish resources, markets and prices received, and fishing costs. In addition, initiatives can affect public confidence in fisheries management and the attendant social license to operate in a marine environment with many competing users and uses. Bycatch management is an important public policy issue for all fisheries sectors—commercial, recreational and subsistence.

This paper addresses biological, economic, and social dimensions of bycatch management including stock assessment, TAC-setting, and regulations including monitoring. Experience is drawn from North America, Australia, and Europe. The important roles of incentives and individual accountability are identified.
The impacts of bycatches of artisanal fisheries on many vulnerable species may dwarf those of industrial fisheries. The coastal environment in which the artisanal fisheries occur is the habitat with the highest densities of many species that feed, haul out, or reproduce in these areas. The lack of observer programs because of physical or economic constraints leaves us working with evidence from strandings or interviews of fishers. A description of the challenges encountered and the solutions developed during a decade of work with many partners in coastal longline fisheries of the eastern Pacific will be used to illustrate the main differences approaching these programs compared to the industrial fisheries.

Knowledge gaps in fishing effort, poor descriptions of the gear and operational modes used, and diffuse and uncontrolled landing patterns are just the tip of the iceberg. These fleets are extremely dynamic, changing gear, operational mode, or fishing grounds in prompt responses to resource availability, economics, or environmental reasons.

Finding the strategies that permit to overcome the difficulties and producing workable solutions is a task we need to undertake. As you cannot succeed in conservation programs on the back of the poverty of these communities, the solutions need to be framed on a clear understanding of socioeconomic realities, and this brings up the need of integrating social scientists and economists in the teams addressing these problems. The solutions need to be economically feasible, work bottom up, and not depend on enforcement or strict controls.
The Price of Bycatch: Examining the Economic Value of Discards in US Fisheries
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Despite ongoing improvements to fisheries management, bycatch continues to be problematic for fisheries around the world, leading to billions of pounds of discarded fish each year. This discarded catch not only has well-documented ecological consequences, but has real and measurable economic costs that are unfortunately rarely assessed. In this study, we developed a basic model for determining the total cost of discarded fish in the United States by compiling species-specific information from the US commercial landings database and nationwide bycatch estimates. In 2010, discarded fish in the US may have been worth almost $1 billion, the majority having been discarded in the northeast region. We examine the total value and average price per pound of bycatch for several fisheries, including which species compose the most significant portions of the value. Our analysis does not include the potential future value of dead juveniles or their unrealized ecological benefits, and yet the results reveal instances where the value of discarded fish exceeds published fishery ex-vessel values. The significant value of discarded fish across all regions of the US highlights the importance of using innovative approaches to manage bycatch and regulatory discarding of regionally targeted species. Here we review the caveats and overall benefits of this approach, including its usefulness for regional, gear-based, and fishery-specific solutions. The goal of this type of work is to inform discussions about increased retention policies and to guide fisheries management decisions in a way that benefits both the marine environment and those stakeholders whose livelihoods depend on it.
Estimating the Economic Impacts of Bycatch in US Commercial Fisheries

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Bycatch presents a challenge to optimizing yield in commercial fisheries, where bycatch can total more than 1 million metric tone per year in the United States. However, the economic impacts of bycatch have not been frequently evaluated in the scientific literature. These economic impacts largely occur from the loss of landings through (1) early closure of fisheries when catch limits of bycatch species are reached, and (2) discards of marketable catch due to regulatory requirements in the fishery.

This presentation will describe the economic impacts of early closures due to bycatch in US fisheries, by describing past case studies as well as evaluating the economic impacts of discarding fish in US commercial fisheries. Premature closures in the fisheries reviewed resulted in potential losses ranging from $34.4 million to $453.0 million annually. Nationally, bycatch estimates in the form of regulatory discards are annually reducing the potential yield of fisheries by $427.0 million in ex-vessel revenues, and as much as $4.2 billion in seafood-related sales, $1.5 billion in income, and 64,000 jobs. This paper will also highlight the importance of conservation engineering to reducing bycatch and the economic impacts of bycatch.
Fisheries bycatch is a worldwide issue. In many developed nations, including Australia, major research, development, management, and fishery innovations and interventions have significantly reduced bycatch rates, interactions, and mortalities. In addition, interventions by conservation agencies have resulted in increased levels of protection (e.g., Marine Protected Areas) for iconic species that have further reduced the risks and impacts imposed by fisheries on many bycatch species. In many cases, there is negligible risk to the sustainability of “bycatch” species from fisheries. However, societal risks of bycatch of some marine species have increased such that the bycatch or mortality of a single individual (e.g., marine mammal) can threaten the ongoing operations of an otherwise sustainable fishery. Developed nations now find themselves at a crossroad—there is an ever-increasing demand for seafood as populations increase, while the fisheries (and catches) of developed nations are being more and more regulated and reduced. This results in either the importing of more seafood from countries with little or no bycatch monitoring or mitigation plans—effectively exporting any bycatch issues—or increasing protein production in other industries (e.g., farming) with other environmental impacts and risks. Using West Australian fishery examples (e.g., Pilbara Fish Trawl Fishery), we argue the need for a wider dissemination of information on bycatch issues in fisheries, including the direct and indirect benefits and costs of increased bycatch regulation, to allow more informed social and political debate on fishery bycatch issues in developed nations.
Likely Economic Impacts under the CFP Landings Obligation and the Challenges That Lie Ahead

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A key element of the newly reformed Common Fisheries Policy (CFP) of the European Union is the progressive elimination of discards in all EU fisheries through the introduction of a landings obligation, starting in 2015. The landings obligation will apply to all species subject to quotas, but there are some exemptions and flexibilities built into the system, such as quota uplift, the use of target quota to cover choke species, and the “de minimis” allowance to continue discarding in exceptional circumstances. Drawing on work recently carried out by Poseidon Aquatic Resource Management on behalf of the UK Discards Action Group (DAG) and the European Commission’s Scientific, Technical and Economic Committee for fisheries (STECF), this paper highlights some of the key economic challenges that the EU fleet will face following the introduction of the landings obligation, including (1) dealing with the restricting effect of “choke” species, particularly in mixed demersal fisheries where improvements in gear selectivity will be key to ensuring many fleets remain viable, and (2) the lack of clarity surrounding the permitted flexibilities contained within the legislation. Ultimately, the way in which the landings obligation is interpreted by the European Commission and implemented by EU Member States could make the difference between continuing to fish and going out of business for some fleets.
Cap-and-Trade Bycatch Management with Costly Avoidance and Stock Uncertainty

Rajesh Singh and Quinn Weninger (presenter)
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We develop a stochastic general equilibrium framework that facilitates performance evaluation of quota- and non-quota-based management plans in fisheries exposed to socially costly bycatch of nonmarket species. We examine fishing behavior, i.e., harvest of the target fish species and costly avoidance of the bycatch species, and bioeconomic performance in a stochastic production environment with and without observability of bycatch, and with and without trade in harvest quotas and bycatch caps. Our results suggest that a precise implementation of a socially optimal management plan is possible only if bycatch is observable and a market for trade in fish quotas and bycatch cap functions costlessly. Non-quota-based regulations, which can be implemented without observability, do not achieve first-best bycatch avoidance and therefore raise fishing costs. The Gulf of Mexico longline reef fish fishery is examined to demonstrate key policy insights from our model.
Invited Talk: Bycatch in the Gulf of Mexico Shrimp Fishery
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Since 1992 fishery observers in the Gulf of Mexico shrimp trawl fishery have secured well over of 31,000 days of observation. Analysis revealed that on average about 27 kg of organisms per hour are taken during trawling operations. Examination of the composition of the organisms showed that about 68% of the catch by weight is composed of finfish (mostly groundfish), 16% by commercial shrimp species, 13% by noncommercial shrimp crustaceans, and 3% by non-crustacean invertebrates.

Although groundfish species make up the majority of the bycatch taken in shrimp trawls, some endangered species (i.e., sea turtles) and marine mammals may have interactions with the trawls, as well as some important commercial and recreational finfish species such as king mackerel (*Scomberomorus cavalla*), Spanish mackerel (*S. maculatus*), and red snapper (*Lutjanus campechanus*). While the average catch of these three finfish species is generally below 0.5 kg per hour, they have received a great deal of attention because of their commercial and recreational importance and the potential for significant impacts on their population abundance through shrimp trawling activities.
Highlights from the First Update to the National Bycatch Report

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The first edition of NMFS’s U.S. National Bycatch Report (published in 2011) documented bycatch estimates, using observer data and self-reported logbook data, for all fisheries for which this information was available in 2005. NMFS completed the First Edition Update 1 in late 2013. This Update includes species-specific bycatch estimates for species included in the First Edition, as well as updated bycatch estimates for all fisheries in the First Edition (with some consolidation of fisheries).

This presentation will describe several enhancements and improvements in bycatch data analysis and bycatch levels in the Update. The Update includes fish bycatch estimates for a total of 573 fish stocks nationwide, an increase from 480 stocks in the First Edition. In addition, NMFS regional teams contributed notable improvements to the Update. The Northeast Region provided fish bycatch estimates for 29 fisheries, compared to 25 fisheries in the First Edition. The Pacific Islands Region added protected species bycatch estimates for American Samoa-based longline fishery. The Southwest Region (now West Coast Region) contributed fish bycatch estimates to this report; the First Edition provided no bycatch estimates for that region.

This presentation also will highlight changes in bycatch levels for specific species and fisheries between 2005 and 2010. For example, Alaska Region longline fishery seabird bycatch was 3,712 birds for 2010, compared to 6,353 birds for 2005. In addition, the bycatch ratio (ratio of total fishery bycatch to total fishery catch) for the Gulf of Mexico shrimp trawl fishery was 0.64 for 2010, compared to 0.76 for 2005.
Comprehensive Analysis of Statistical Precision of US Bycatch Estimates: Persistent Uncertainty and Future Priorities

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The Magnuson-Stevens Act requires standardized bycatch reporting methodologies to accurately estimate bycatch, but few fisheries in the United States have implemented them to date. This lack of progress has perpetuated poor data quality, which undermines fisheries management goals, hinders rebuilding timelines, and could even compromise fishing opportunities. We conducted an analysis of the overall statistical precision within the National Marine Fisheries Service National Bycatch Report by compiling the number of stock bycatch estimates accompanied by a coefficient of variation (CV) and the number of those values that meet national guidelines for precision goals. The recently published draft update of the National Bycatch Report estimates bycatch for 80 fisheries across six regions. Our results show that only one-third of stock bycatch estimates are accompanied by a CV and less than one-quarter of those CVs meet the 30% precision goal. Overall, only four fisheries have average CVs less than 30%, with regional averages of 50% and 140% in the Northeast and Southeast, respectively. While significant progress has been made since 2005, this high level of uncertainty fails to meet established national precision standards and signifies that existing bycatch estimates are often insufficient for informing in-season management measures. This comprehensive analysis identifies priority fisheries and stocks in need of continued improvement and shows the importance of alternative approaches to account for this uncertainty such as increasing the mathematical buffer used when calculating annual catch limits. It is imperative that robust standardized bycatch reporting methodologies are established across all US fisheries in the near future.
The Risk-Matrix Approach to Evaluating Fisheries Bycatch
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Managers of limited resources must evaluate the risks of failing to meet stated objectives. The National Standards for managing US marine fisheries includes requirements to incorporate the best available science, to consider variations and contingencies in making decisions, and minimize bycatch and resulting mortality. For the best available science to translate into the best scientific advice, it is paramount that complex concepts and analyses be simplified to compete with conflicting anecdotal information that is prone to recency bias and conventional wisdom. Risk matrices offer a potential way to prioritize activities among multiple projects and potential outcomes. Bycatch ratios that represent fisheries inefficiency, and bycatch amounts that represent fishery impact, were extracted from the First Update to the U.S. National Bycatch report and used to construct a risk matrix for 60 fisheries. Terciles from the cumulative distribution of each metric were used to identify low, medium, and high values that in turn were used in a “stoplight” visualization (e.g., high values are assigned the color red). Being simplifications, risk matrices are prone to subjective interpretation. However, data in this exercise were sufficient to debunk the notion that fisheries with high bycatch metrics are restricted to certain gear types or geographic regions. The risk matrix is one alternative approach to relying on the quantitative values of a single metric such as bycatch ratios or uncertainty values to prioritize where to direct cooperative research and monitoring efforts to reduce and track fishery bycatch.
Assessment of Cumulative Fishing Effects on Sustainability of Bycatch Species

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A population of a bycatch species may be subjected to fishing mortality from multiple fisheries or gear types. Previous ecological risk assessment methods typically assess stressors separately on a fishery-by-fishery basis. By contrast, it is the cumulative impact from all fisheries and gears on each individual species that determines the species’ overall sustainability. We extended the sustainability assessment for a fishing effects method to evaluate cumulative impacts on bycatch species from multiple fisheries. The method utilizes existing data, particularly fishery-dependent data sources, to estimate fishing-induced mortality. Sustainability benchmarks are developed from meta-analyses that link fishing mortality-based reference points with simple life history parameters. Cumulative impact does not increase linearly as the number of fisheries increases. Typically, only a few fisheries cause the majority of the fishing mortality to particular species while many fisheries have very minor effects. The method or some components of it could be adopted by other fisheries for cumulative risk assessment of bycatch species.
The Ross Sea toothfish fishery uses bottom longline gear to target two species of toothfish (*Dissostichus mawsoni* and *D. elegenoides*) in continental shelf, slope, and seamount areas at typical depths of 800-1,800 m during the Austral summer. It is a high seas fishery managed by CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) since 1997 with vessels from up to 12 nations participating. The main bycatch taxa are macrourids (rattails), skates, channichthyids (icefish), muraenolepidids (eel cods), morid cods, and nototheniids (rock cods and ice cods), comprising about 16 species. With the exception of skates, they are all prey items of toothfish. Each taxon occurs over only a portion of the range of the fishery and catch of some species has been minimized by area closures. With two observers on each vessel all catch is weighed by haul, and biological sampling occurs following a data collection plan. New, cryptic species are still being described. Macrourids are the most frequent bycatch by number and weight (7% of reported catch weight). Catch limits are in place for macrourids, skates, and other minor species. A move-on rule triggered by exceeding 1 ton of macrourids in a haul or a total macrourid weight exceeding 16% of the toothfish weight by vessel in any of eight subareas, has reduced macrourid bycatch by approximately 50% since 2007. Stock assessment methods are in development for macrourids and skates.
Portside Bycatch Sampling and Comparative Sampling of the Atlantic Herring (Clupea harengus) Fishery

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The Maine Department of Marine Resources (DMR) has amassed ten years of information and data from the DMR Portside Bycatch Sampling Program of the Atlantic herring (Clupea harengus) fishery and has recently been compared against the National Marine Fisheries Service (NMFS) At-Sea Monitoring Program on concurrently sampled trips. Portside bycatch and incidental catch sampling offers a lower cost and lower hazard solution to monitoring high volume fisheries when compared to at-sea observations.

Due to the potential listing of river herring as an endangered species and other management actions to limit bycatch and incidental catch of river herring in the Atlantic herring fishery, an analysis and comparison between co-occurring trips was conducted looking exclusively for significance of river herring. This test and comparison was also useful to examine methodological differences between the at-sea and portside monitoring programs and addressing which methods could be aligned to better document bycatch of many other small-bodied species.

While portside sampling doesn't address at-sea discards, the data on small bodied pelagics are, in many ways, better than sub-sampling at sea. Portside offers a safer and cheaper sampling platform, with zero time spent on-board fishing vessels, where labor costs, insurance, and safety issues can accrue while searching for and landing fish.
Evaluation of Design-Based Estimators in Federal Groundfish Fisheries off Alaska

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Over time, incremental changes to the methods used to estimate total catch in the federal groundfish and halibut fisheries have provided opportunities to expand the types of statistics used for catch estimation. These changes coincide with new monitoring requirements associated with catch share programs, improvements in monitoring and reporting technology, improvements in sampling design, and improvements to database architecture and estimation routines. In 2013, a major change to regulations governing the North Pacific Observer Program allowed the National Marine Fisheries Service to control the deployment of observers into the fleet. This change replaced regulations that allowed vessels to select when to carry an observer. Taken together, these important changes allow us to take advantage of the randomized sampling design and consider using design-based estimators for total catch estimation. At present, the expansion of observer sample data to discard estimates for observed trips is based on imputation routines and the use of ratio estimators. However, recent research indicates design-based estimators are robust to highly variable sample data that is encountered for less common species, such as bycatch of nontarget species. Further, design-based estimators allow for estimation of precision under the hierarchical sampling procedure currently employed. In this presentation we investigate patterns of total discards and evaluate how the differences in the precision of trip-total discard estimates relate to species rarity. We focus on fisheries with complete observer coverage (all trips observed), recognizing the methods used in this study may have application to fisheries with random deployment of observers (partial coverage).
Opportunities for Bycatch Assessment Using Electronic Monitoring

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Electronic Monitoring (EM), an automated array of ship-board closed circuit television cameras and sensors, has been tested in a variety of fisheries across multiple jurisdictions, geographies, gear types, catch profiles, and monitoring objectives. Many of these studies show promise, yet since their introduction over a decade ago, very few fisheries have adopted technology-based monitoring. As compared with observer programs, EM requires a much more comprehensive program design. A more holistic view is needed to link the fishery characteristics and monitoring needs with technology capabilities, monitoring options, regulatory framework, incentive systems, and program operational requirements (i.e., field service infrastructure, data analysis specifications, and other program components) to ensure the program is efficient, effective, and integrated with management needs. In terms of addressing bycatch issues in fisheries, EM can be used very effectively by considering monitoring options along a gradient of increasing complexity: mitigation compliance, maximized retention compliance, catch accounting for selected discards, and catch accounting for all species. Often, these options are integrated with other information sources (e.g., using EM to audit vessel-reported data) as opposed to being a single, standalone solution. The efficacy of these monitoring options varies by fishery type, but as compared to observers, they scale more effectively to high fleet coverage levels and are potentially much more cost effective. We draw from case studies to show how different approaches can be used to address bycatch issues, highlighting both challenges and opportunities to facilitate more effective planning. We also provide an evaluation framework for different fisheries monitoring strategies.
Evaluating and Improving Survivability of Cusk Bycatch Discarded in the Gulf of Maine Lobster Trap Fishery

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Nontargeted species account for an estimated one-quarter of the world's fisheries catch, often resulting in wasted valuable resources, a potential threat to rare or endangered species, and unaccounted fishing mortality of exploited stocks. The Maine lobster fishery is considered to be responsible for an unknown quantity of cusk (Brosme brosme) bycatch, which is a Species of Concern and candidate for the Endangered Species Act. Cusk experience barotrauma, physical trauma induced by gas expansion from decompression, during surfacing events such as hauling up a lobster trap. Maine state law mandates lobster harvesters to discard nontargeted species caught in their traps. Upon discarding, cusk are positively buoyant and are incapable of quickly changing their buoyancy, which prevents them from returning to depth to avoid predation from birds and seals. Research on other species has demonstrated that assisted recompression of barotraumatized fish increases their chance of survival. In this research, collaborative experiments are being conducted with volunteer Maine lobstermen to create protocols for discarding cusk to increase their survivability after a surfacing event. Commercial lobster harvesters are tagging bycaught cusk, then replacing those fish in the front part of the trap to be recompressed. These fishermen are recording their observations during their first encounter and again when they re-haul the same trap to evaluate survival rates of recompressed cusk. To evaluate lobster traps as a suitable mechanism for recompression, incidentally caught cusk are being monitored with underwater cameras to record their behavior. The survival rates of discarded cusk are then evaluated based on observations by fishermen and researchers. The preliminary phase of this study has indicated a high rate of survival of recompressed discarded cusk. Based on the analysis, we propose a protocol to increase survivability of bycaught cusk that can reduce the unintended mortality of cusk and similar groundfish species in the Maine lobster fishery.
Longline-Caught Skate (Rajidae) Injuries and Handling: Prelude to Mortality Estimation

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Skates (family Rajidae) are long-lived with low fecundity, and thus are particularly vulnerable to fishing pressures, in directed fisheries or more commonly as bycatch in other target fisheries. In the North Pacific, skates are caught incidentally in appreciable numbers across a wide range of target fisheries and gear types. Longline gear is responsible for the greatest proportion of skate catch, about 70%, in the observed fisheries of the Bering Sea and Gulf of Alaska. The majority of these skates are discarded as soon as they reach the vessel and though alive, they are generally released with injuries due both to gear capture and crew handling during release efforts. Currently, management assumes 100% mortality of all skates regardless of disposition. While this approach forms an important precautionary position in the face of scant data to the contrary, anecdotal and early observations suggest that skates can indeed survive a capture episode.

Presented here are the findings of a study undertaken onboard commercial freezer-longliners to describe, as well as classify into discrete severity categories, the injuries that skates sustained following longline capture and subsequent discard. Furthermore, the study examined the effects on injury severity between handling techniques typically seen in commercial operations and those of a more careful handling regime akin to that mandated for bycatch Pacific halibut (*Hippoglossus stenolepis*). With this understanding of discarded skate handling and injuries, studies may be initiated to quantify an accurate fishing mortality rate for management purposes.
To quantify total fishing mortality it is necessary to incorporate mortality rates attributed to bycatch, including animals that are discarded, escape the fishing gear, and interact with the gear without being caught (“unobserved bycatch”). The Reflex Action Mortality Predictor (RAMP) approach has been increasingly used to determine bycatch mortality rates in fisheries. This methodology creates a RAMP curve that relates reflex impairment to probability of mortality. RAMP can be applied regardless of environmental or biological factors, is relatively not time-intensive or expensive, generates results quickly, and reflects physiological damage that cannot be seen. RAMP can be used to compare gear configurations and fishing practices to identify ways to increase survival of bycaught animals. As RAMP becomes a more prevalently used methodology it becomes important to evaluate the efficacy of its application. We evaluated the flexibility of RAMP by creating a RAMP curve for Tanner crab (*Chionoecetes bairdi*) discarded from the groundfish bottom trawl fishery in the Gulf of Alaska and comparing it to a previously established RAMP curve for unobserved Tanner crab bycatch (encountered gear on the seafloor) from the bottom trawl fishery in the Bering Sea. We detected differences between the two RAMP curves. While rates were similar for crab with all or no reflexes missing, discarded crabs with intermediate reflex impairment had lower mortality probabilities than those from the prior study. Our results indicate that a RAMP curve may produce more accurate mortality estimates when applied to animals experiencing similar stressors than those evaluated to create the curve.
Mortality Rates of Tanner Crab (Chionoecetes bairdi) Bycatch Discarded by Alaska Bottom Trawlers

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Crab bycatch by bottom trawlers has been a significant issue in the management of Alaska's marine fisheries, creating conflict between two of the largest fisheries of their kinds in the world (Alaska crab and flatfish fisheries). Mortality rates for discarded crabs are poorly understood, even though bycatch numbers have been well tracked by an onboard observer program. The one study providing initial mortality estimates involved catch handling practices differing significantly from current Alaska trawl fisheries practices, including longer handling times than presently experienced by crab bycatch. The reflex action mortality predictor (RAMP) has proven effective for accurately and efficiently estimating mortality rates, including their application to Alaska crab species. We conducted reflex assessments of Tanner crab (Chionoecetes bairdi) discarded during fishing aboard Alaska bottom trawlers and applied a RAMP to estimate discard mortality rates. Estimated mortality rates for Gulf of Alaska trawling averaged nearly 40% lower than those observed by Stevens published in 1990. This reduction was consistent with a significant relationship between handling time and mortality rates, indicated in both current and previous studies.
Quantification of marine mammal and seabird bycatch is important in the context of conservation and management of protected species. Hitherto, using onboard observers has been the most reliable and accurate method; however, observer programs can be prohibitively expensive. To reduce price and increase coverage closed-circuit television (CCTV) cameras have been used to document bycatch of marine mammals. Under the Danish catch quota management system six Danish commercial gillnetters were equipped with remote electronic monitoring (REM) systems. The REM systems provided video footage, time, and position of all net hauls and catches. The results showed that REM system gave more reliable results compared to fishermen’s registration since the bycatch, in many cases, had already dropped out of the net before coming on board. Furthermore, very high coverage at low cost was obtained with REM. Based on these results eleven gillnetters fishing in the inner Danish waters have since 2012 been equipped with REM systems collecting data on bycatch of marine mammals and seabirds. Preliminary results show that species identification of seabirds was possible from the video footage and had a large effect on bycatch rates. In 2014 the REM coverage will be expanded even more by adding additional seven vessels, fishing mainly in the Baltic collecting bycatch data on the endangered harbor porpoise population and other marine mammals and seabirds.
Data Management Technology for Monitoring Bycatch in International Fisheries: A Case Study

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The incidental capture or bycatch of nontarget species in marine fisheries is occurring at an unsustainable level. Seabirds are particularly affected, with fishery interactions considered the key threat to most species. Longline and trawl fisheries have been recognized as having a significant impact on albatross, petrels, and shearwaters. Seventeen of the 22 species of albatross are currently threatened with extinction.

In 2005 BirdLife International founded the Albatross Task Force (ATF)—an international team of mitigation instructors working directly with the fishing community to demonstrate the best practice design and use of mitigation measures. In order to effectively monitor and record seabird interactions, mortality events, and technical aspects of mitigation design, BirdLife International retained the services of Olrac SPS to customize its GIS-based Olrac Dynamic Data Logger software to meet the data collection and reporting needs of ATF’s onboard observer team. The ATF version of Olrac allows observers to capture 320 different fields including target and bycatch species, fishing gear configuration, mitigation measure configuration plus wildlife surveys and extensive environmental variables. Data can be collected in many forms and formats including pictures, video clips, and free text.

ATF is currently using Olrac DDL in eight countries in Southern Africa and South America. In addition ATF deployed three shore units of the Olrac system as a central hub of data in each country plus a centralized meta-unit capable of integrating data from all countries into a master database.
Overlap of North Pacific Albatrosses with the US West Coast Groundfish and Shrimp Fisheries

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A recent mortality of an endangered short-tailed albatross (*Phoebastria albatrus*) and annual mortalities of black-footed albatross (*P. nigripes*) in the hook-and-line fishery for sablefish (*Anoplopoma fimbria*) has triggered conservation concern for North Pacific albatrosses in the West Coast groundfish fisheries. We used a combination of seabird data (both fishery-dependent and fishery-independent) and fishing effort data to evaluate the relative fisheries risk of five west coast groundfish fisheries and one shrimp fishery to black-footed, short-tailed, and Laysan albatrosses (*P. immutabilis*).

To assess risk, an overlap index was derived as the product of total fishing effort and fishery-independent at-sea survey density of black-footed albatross. This index was used as the primary tool to estimate overlap with the endangered, relatively rare short-tailed albatross, which show similar habitat utilization from satellite telemetry tracks. Telemetry data indicate Laysan albatross primarily occur offshore beyond observed fishing effort. Black-footed and short-tailed albatross-fishery overlap was highest at the shelf-break (201-1,000 m) north of 36 N. Overlap and reported albatross mortality indicate that the sablefish longline and Pacific hake (*Merluccius productus*) catcher-processor fisheries pose the greatest risk to these species; the nearshore rockfish (*Sebastes* spp.) longline, pink shrimp (*Pandalus jordani*) trawl, California halibut (*Paralichthys californicus*) trawl, and non-hake groundfish trawl fisheries pose relatively little risk. Implementing proven seabird bycatch-reduction measures will likely minimize albatross mortality in the highest-risk fishery, sablefish longline.
Sperm whale depredation of sablefish from demersal longline gear presents an economic hardship for fishermen and also may cause conservation issues due to the risk of whale entanglement. This is a concern because of the listing of sperm whales under the U.S. Endangered Species Act.

Information on the timing and movement patterns of sperm whales in the Gulf of Alaska may provide a means for fishermen to avoid whales. Toward that goal, the Southeast Alaska Sperm Whale Avoidance Project (SEASWAP) used photography to identify 111 individuals, and deployed satellite tags on 21 whales between 2007 and 2013 to document movement patterns and habitat use. Tags were provided through funds from industry and government collaboration.

In 2007, 2009, 2010, and 2013 locations of sperm whales were available in near–real time to fishermen via the Alaska Longline Fisherman’s Association (ALFA) website. Coupling satellite tracking and photographic data provided information on movements and associations of 12 sperm whales seen ten or more times (range = 10-21; $\bar{x} = 12.9\pm3.5$ sd). We identified whales with repeated associations and areas of intense residency in fishery areas. Tags transmitting depth and location provided additional details on the foraging behavior by sperm whales. Future use of these methods will determine if some whales are skilled, repeat depredators across years. These approach would give fishermen an option to avoid fishing at known hot spots where whales are predicted to be present based upon past sightings, thereby reducing the opportunity for interactions between whales and fishermen in Alaska waters.
Invited Talk: Review of Fishing Technology to Reduce Bycatch in Asia

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The amount of discards in the Northwest Pacific is estimated to be 9 million tons, which accounts for 33.8% of the global discards according to FAO Technical Paper 339. The causes of bycatch are different by region, target species, fishing gear and method, and fishing ground condition. Bycatch occurs not only by active fishing methods such as trawling, but also by passive fishing methods, including gillnets, traps, and longline fisheries.

The authors introduce the current status of bycatch and discards and the development of bycatch reduction devices applied in different fishing gears and methods in Asia. TED, BRD, and JTED are applied in trawls and shrimp trawl fisheries. The typical approach to reduce bycatch in gillnets and traps is mesh selectivity and selectivity of escapement ring.
Study on the Juvenile and Trash Fish Excluder Devices (JTEDs) in the Philippines

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Demonstration and experiments on juvenile and trash fish excluder devices (JTEDs) were conducted and provide an opportunity in the industry to participate in identifying the most appropriate type of device. Experiments were conducted in Manila Bay, Maqueda Bay, Lingayen Gulf, San Miguel Bay, Samar Sea, and Visayan Sea. Variations of JTEDs in the experiments were VRSG 1, 1.5, 2, and 3 cm; HRSG 1 cm and 1.5 cm; SMSG 4 cm and 5 cm bar; RSW, SMW, and SCW on 1 hour standard tows. The fish eye was also introduced.

The catch in the areas covered during the experiments showed that by weight, commercial fish made up about 1.7% for shrimps, 09.5% for juveniles, 24.9% for hoya, 5.9% for trash, and commercial species made up the bulk with 58%. Results indicated that overall escapement rates for all species groups over the JTED types ranged from 11% to 52%, with highest recorded in SG 2 cm. The SMW with 4 cm mesh bar and RSW were observed to be unsuitable. Escapement rates for juveniles ranged from 8.7%-94% and 13.9%-70% for trash fish, and 0-47% and 0-50% for commercial fish. Multivariate analysis reveals a few significant differences in the Samar Sea/Maqueda Bay and Lingayen Gulf runs, indicating the better performances of SG 1 and SG 1.5 when the escapement rates of the various catch grouping are considered. In the Visayan Sea, HRSG 1.5 cm garnered the highest CPUE with 54.6 kg/hr followed by HRSG 1.0 cm with 39.4 kg/hr, both grids of which had 4 settings each. All in all, the total CPUE of all operations were 37.04 kg/hr with a total of 23 fishing operations.
Bycatch Reduction Devices: Development, Adoption, and Implementation?

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Despite a plethora of conservation engineering research initiatives over the past decade, bycatch and discarding continues to be a problem in fisheries in the Northeast USA and worldwide. While a number of successful bycatch reduction devices have been developed and introduced into fisheries regulations, many more examples of devices or strategies have been either unsuccessful or have not been adopted by fishermen or managers. The reasons underlying lack of adoption are complex but may include factors such as reluctance of fishers to accept any loss of target catch, reticence of managers to change status quo, concerns regarding suitable enforcement measures, and lack of clear, unequivocal scientific evidence of the efficacy of the device or strategy.

Here we provide examples illustrating where bycatch reduction devices and/or strategies have been successfully introduced, examples where devices exist but have not been implemented, and others where devices and/or strategies have been introduced and subsequently dropped from use. We include examples of gear design and modification, discussion of bycatch reduction strategies such as quantification of temporal and spatial distributions of fish, and introduction of bycatch caps or quotas that create incentives to avoid bycatch. We discuss potential reasons for the apparent general lack of adoption of bycatch reduction devices and make recommendation regarding mitigation measures and reduction programs that hold potential for addressing this issue.
Environmentally Friendly Fishing Gear with Bio Resin for Reducing Ghost Fishing and Bycatch of Nontarget Species

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The number of fishing vessels operating in coastal waters of Korea is about 77,300, and of them approximately 21,000 and 8,800 vessels involve in gillnet fishery and trap fishery, respectively. In general, the gillnet fishery uses 500 panels per vessel, and about 50 panels (10%) per year are lost. In the trap fishery, a total of 2,500 traps are used, and about 500 traps per vessel are lost during a year. Ghost fishing occurs because lost synthetic net is not easily degraded under natural sea conditions. Biodegradable monofilaments for gillnet and trap were developed at NFRDI for reducing ghost fishing and protecting the marine ecosystem. It was made with PBS (polybutylene succinate) and PBAT (polybutylene succinate adipate-co-terephthalate) resin. The developed bio-monofilament is degraded by microorganisms (bacteria, fungi, etc.) after two years in the sea. The fishing performance of PBS net is similar to that of PA (e.g., nylon). Representative fisheries that used biodegradable fishing gears are snow crab gillnet and swimming crab gillnet. To test the fishing performance of biodegradable materials, onboard surveys were conducted with commercial gillnetters. Results show that the overall catch of bio-gillnets was similar to that of commercial nets, and catch of individuals smaller than minimum landing size by bio-gillnets was less than by commercial gillnets. Therefore, it is shown that biodegradable fishing gears are effective for reducing ghost fishing and bycatch of nontarget species.
Bycatch is among the most problematic aspects of modern fishing from a conservation perspective. In addition to the sheer volume of bycatch globally, unselective fishing poses a serious threat to numerous species of ocean wildlife and threatens the commercial viability of a number of mainstream fisheries. In recent years, improvements to fishing gear and practices have played an important role in reducing bycatch, as modifications have increased the chances for nontarget species to escape or avoid capture altogether.

In response to the bycatch concern, World Wildlife Fund initiated the first International Smart Gear Competition in 2004, with the goal of identifying innovative and practical modifications to currently used gear with potential for significantly reducing bycatch. The competition, which now offers cash prizes in excess of $50,000, has been held five times and attracted more than 300 entries from 40 countries worldwide. It has also served as a positive way for conservation interests to cooperate with industry and a cornerstone for cross-sector collaboration between nongovernment organizations, industry, and government.

To date, 40% of the winning entries are being utilized in commercial fisheries, and advancement of the winning ideas is seen as an integral part of this strategy to address the issue of bycatch.
Reducing Bycatch of the Japanese Snow crab (Chionoecetes opilio) Using Simple Modified Gears in the Danish Seine Fishery

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The Japanese snow crab is an important forage species of the Danish seine fishery in the western part of the Sea of Japan. Bycatch of snow crabs during the fishing season for other species, such as flatfish, is inevitable because the species are distributed within almost the same depth range. Bycatch posed major problems toward efficient use of resources. We aimed to develop bycatch reduction gears for this fishery by altering two types of conventional Danish seine net. These modified nets had a simple design to make it easier to introduce into a local fisheries community.

The escape opening was installed in each type of net equipped with a normal ground rope and a raised footrope on the forward part of the net and in front of the codend, respectively. During experimental operations, a cover-net was mounted over the escape opening on both the nets to catch excluded crabs and other species. The entire catch in the codend and the cover-net from each tow was sorted and weighed separately by species to estimate the ratio of bycatch on each species.

The reduction rate of the snow crab for the net with normal ground rope was 37.9%-72.9% and with raised footrope was 31.2%-62.7%. The catches of red halibut, the most important flatfish, was also reduced with a range of 6.3%-23.4% for the normal ground rope net and 2.0%-5.2% for the raise footrope net. These values are flexible and could be changed to modify specifications around the escape opening.
Reducing Bycatch in New England’s Groundfish Sectors: The Development of a Fishing Area Selectivity Tool

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A lack of real-time data on which to base fishing behavior has significant implications for avoiding bycatch in New England’s groundfish fishery. Groundfish sectors—fishing cooperatives created through a transition to catch share management—are subject to time lags in management decisions on bycatch as information is gathered and analyzed. Through support from the NOAA Fisheries Northeast Cooperative Research Program, the Gulf of Maine Research Institute has developed a near real-time spatial/temporal fishing area selectivity tool (FAST) in partnership with the groundfish industry. The project has developed a web-based data portal and mapping tool that enables industry-led bycatch avoidance efforts outside of the regulatory process for harbor porpoise, Atlantic halibut, and windowpane flounder. The tool allows near real-time catch data to be presented with historical catch data, oceanographic information, and management information. The initial project focus in 2010, of providing fishermen with a tool to share individual catch data with other fishermen in order to target allocated species and avoid others, was met with resistance. Initial allocations varied widely among fishermen—and one boat’s target species was another’s “choke” stock. Many lessons were learned, and the project focus shifted to reduce bycatch on species the entire fleet has a vested interest in avoiding. In New England, bycatch can lead to time/area closures of prime fishing grounds and gear restrictions, severely restricting the fishing industry’s ability to fully access the annual catch limits (ACL) of allocated stocks. Work is ongoing, and our fleet-wide approach brings new opportunities and challenges to bycatch avoidance.
Trawl designs to reduce discards often utilize behavioral differences between species and mechanical means due to size differences. An otter trawl may be divided into three regions that correspond to capture and retention stages: ahead of trawl, at the mouth of trawl, and in the aft belly including codend. Animals that are able to escape the trawl in the earlier stages of capture usually suffer less physical stress and mechanical injury, thus less capture-induced mortality. Trawl designs that encourage escape of discard species in the early stages of capture are thus preferable. While the Nordmøre Grid may be one of the most successful bycatch reduction devices in trawls targeting coldwater shrimps, including the northern shrimp (*Pandalus borealis*), it cannot eliminate small finfish and small shrimp that can pass through the space between the bars. During the last decade, several gear-related research projects were systematically conducted in the Gulf of Maine northern shrimp trawl fishery, including semi-pelagic trawling, floating bridles, topless trawl design, a radically modified grid (Rope Grid), and a size-sorting grid. This paper will review and summarize these projects and provide fishing technologists, fishery managers, and the fishing industry the state of knowledge in shrimp trawl designs and modifications for the Gulf of Maine shrimp trawl fishery. These designs may also be applicable to other shrimp and prawn fisheries around the world.
Anglers fishing aboard charter boats in Alaska release as many halibut as they retain, both as regulatory and voluntary discards (catch and release). Halibut are hardy fish but some succumb to injury, exhaustion, or predation. Recent studies suggest release halibut mortality in sport charter fisheries is 5-6%.

This year two projects were initiated to reduce sport halibut release mortality. The Alaska Marine Conservation Council and Alaska Sea Grant were funded by the National Fish and Wildlife Foundation to develop and extend to industry a set of release best practices in a program called Every Halibut Counts. A charter captain committee developed the best practices recommendations. The Alaska Charter Association received funding from NOAA’s Bycatch Reduction Engineering Program to also address means of reducing halibut release mortality. This project applies smartphone digital imaging technology to allow the user to estimate the length and weight of a halibut while it is still in the water, by simply capturing an image of the halibut’s head. Anglers may then decide whether to retain or release a fish, reducing physical handling and decreasing time out of the water.

The two projects are coordinating their messages and their outreach to maximize project impacts. While the target audience is charter boat captains and crew, the combined effort will reach thousands of unguided (private boat) anglers as well. The presentation will list best practices measures, description of measurement technology, outreach protocols, and early responses.
Capture Environmental Conditions of *Pteroplatytrygon violacea* in Waters Near Gilbert Islands

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Studies on capture environmental conditions of the stingray *Pteroplatytrygon violacea* can contribute to a reduction in bycatch of *P. violacea*. In this study, the *P. violacea* nominal bycatch rates of traditional gear, experimental gear, 16/0 circle hook and 18/0 circle hook, and environmental variables were obtained from two surveys of waters near Gilbert Islands in longlining operations from 4 October 2009 through 25 December 2009 and from 20 November 2010 through 20 January 2011. *T*-test was used to test if there were significant differences among the *P. violacea* bycatch rates for four types of fishing gear. Cluster analysis was used to examine the *P. violacea* capture environment. The results showed that: (1) The *P. violacea* nominal catch rate, in individuals per thousand hooks, for traditional gear was 3.790, for experimental gear 1.522, for 16/0 circle hook 2.174, and for 18/0 circle hook 0.435; (2) the experimental gear and 18/0 circle hook could significantly reduce the bycatch rate of *P. violacea*; (3) for high catchability of *P. violacea* the depth was 40-80 m, temperature 29.0-29.9°C, salinity 35.40-35.49, chlorophyll *a* concentration 0.440-0.459 μg/L, and dissolved oxygen (DO) concentration 4.50-4.99 mg/L. This study suggested that the following mitigation measures could be used to reduce the *P. violacea* bycatch rate: (1) using 18/0 circle hook; (2) setting the hook to depths deeper than 120 m, water temperature lower than 26°C, salinity range lower than 35.40, chlorophyll *a* concentration lower than 0.300 μg/L, and dissolved oxygen concentration lower than 3.50 mg/L.
Innovative Camera Applications for Electronic Monitoring

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Electronic monitoring has been shown to be an effective tool to satisfy a variety of monitoring objectives in compliance-based programs. However, these systems have not been shown to be an effective tool in delivering detailed data sets similar to information collected by an observer.

Development of new camera-based systems, methods, and tools is critical for collecting scientific data to inform management. A new camera system developed at the Alaska Fisheries Science Center greatly improves the functionality and addresses many of the issues previously identified with EM systems. This system provides the ability to not only monitor fisheries with cameras, but to automatically collect length measurements. This system will also identify and automatically capture high quality (HD) stereo images of individual catch events for efficient identification of catch to species or species group. Because only images of catch events are stored and reviewed, post-processing and storage costs will be much lower. Reduction in the data volume resulting from this system will facilitate data transfer and management. Images will be time stamped and linked to GPS information, allowing precise location of species-specific catch. This will enable mapping of high bycatch rate areas, improving future management strategies to lower bycatch. Lower overall costs will extend coverage rates to a wider range of vessel types and sizes where it is impractical to place an observer. A cost-effective camera-based system that collects scientific data on fishery impacts will provide greater certainty for resource management and support sustainable fishing practices.

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Recent federal budget cuts and looming industry cost sharing mechanisms have revealed a need to explore more cost effective and sustainable alternatives to at-sea monitoring in New England’s groundfish fishery. Electronic monitoring has proven to be a successful alternative in areas such as British Columbia’s groundfish fishery, and has gained attention across New England through recent developments from the National Marine Fisheries Service and the New England Fishery Management Council. Despite these efforts, further research is needed to operationalize catch-handling protocols for effective data analysis, along with affordable methods to successfully implement electronic monitoring in New England’s groundfish sector. The Gulf of Maine Research Institute, with The Nature Conservancy, Maine Coast Community Sector, and Ecotrust Canada, is conducting a two-year Electronic Monitoring Project that will develop and test an affordable, open-source electronic monitoring system on seven active groundfish vessels across both gillnet and trawl gear types. The data collected will meet federal technical specifications and be compared to data collected by the fishermen as well as that of at-sea-monitors. It is hoped that the work will validate self-reported data, build on existing federal initiatives, and introduce an additional electronic monitoring provider to increase capacity and further its operationalization in preparation for regulation approval.
The ASSF Skipper Workshops: Working with Fishers to Reduce Bycatch in Tuna Purse Seine Fisheries

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Since 2009 the International Seafood Sustainability Foundation has been organizing workshops between tuna fisheries scientists and fishers from the principal fleets in the Indian, Atlantic, and Pacific Oceans to reduce bycatch associated with fish aggregating devices (FADs). Over 400 skippers and other 300 key stakeholders (crew, ship-owners, fleet managers, scientists, managers) from Asia, Europe, Latin America, and Africa have participated so far. The aim of the workshops is to identify and develop the best technological solutions and fishing practices to minimize bycatch. Fishers have a wealth of experience and knowledge on fishing gear and fish behavior. Ideas and feedback provided by skippers during the workshops help scientists come up with new ideas and refine their bycatch mitigation trials conducted during the ISSF research cruises onboard chartered commercial purse seiners. Themes discussed in the workshops include development of non-entangling FADs, acoustic selectivity, and gear modification for bycatch liberation. Collaboration with skippers from different fleets ensures that technological methods developed are appropriate to their ocean and the characteristics of their vessels. Involvement of fishers in developing bycatch reduction tools legitimates and facilitates the adoption of associated measures.
Best Practice Seabird Bycatch Mitigation for Pelagic Longline Fisheries Targeting Tuna and Related Species
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We extended our collaborative fisheries research model developed in Alaska fisheries to preventing albatross and petrel bycatch in the Asian distant water tuna fleet. Specifically, we tested combinations of three primary mitigation measures in a pelagic longline fishery with one of the highest rates of interaction with what may be the world’s most challenging seabird assemblage (dominated by Procellaria genus petrels). Multiple measures were used to compare the performance of weighted vs. unweighted branch lines set with two bird-scaring lines—hybrid lines with long and short streamers—during daytime and nighttime. The weights used were a novel double-weight configuration. Secondary attacks on baits brought to the surface by white-chinned petrels drove albatross mortality. Regardless of time of day, weighted branch lines with two bird-scaring lines, deployed and maintained with an aerial extent of 100 m, reduced bird attacks by a factor of 4, and secondary attacks and seabird mortality by a factor of 7, compared to unweighted branch lines, with little effect on fish catch rates and with no injuries to crew. This combination yielded zero bird mortalities when gear was set at night. We conclude that the simultaneous use of two bird-scaring lines, weighted branch lines, and night setting meet our criteria for best-practice seabird bycatch mitigation for the joint-venture fleet targeting tuna and related species in the South African EEZ. Given that these measures were successful in one of the most challenging pelagic longline fisheries, they are likely to be widely applicable to pelagic longline fisheries using similar gear.
Illumination of Gillnets Reduces Sea Turtle Bycatch

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Gillnet fisheries have been associated with high bycatch rates of marine megafauna such as sea turtles. Altering the visual cues associated with gillnets may be a useful strategy in reducing sea turtle bycatch. We studied the effectiveness of illuminating nets as a strategy to reduce sea turtle bycatch in small-scale bottom-set gillnet fisheries.

We conducted experiments in Sechura Bay, Peru, in which 115 paired fishing sets (control and treatment) were monitored between January 2011 and July 2013. We observed a 65% reduction in the mean bycatch rate of green sea turtles (Chelonia mydas) and no change in the target catch rate on treatment nets illuminated by green LEDs. This suggests that increasing net visibility could be an effective sea turtle conservation tool. Bycatch declines were also seen in guanay cormorants (Phalacrocorax bougainvillii, 89% decline) and Pacific seahorses (Hippocampus ingens, 59% decline). In addition, we examined the effectiveness of illuminating gillnets with ultraviolet (UV) light-emitting diodes (LEDs) that had a peak wavelength at 396 nm as a strategy to reduce green sea turtle interactions in coastal gillnets off Baja California, Mexico. We observed a 39.7% reduction of the mean sea turtle capture rates in the illuminated nets versus control nets. We also tested UV net illumination in a commercial bottom gillnet fishery to quantify the effects on target fish catch rates and catch value. Illuminated nets did not significantly affect the target fish catch rate or catch market value.
Can We Be as Clever as a Sperm Whale? Efficacy of Countermeasures to Reduce Sperm Whale Depredation on Demersal Longlines in the Gulf of Alaska

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Since 2003, fishermen and scientists have been working collaboratively under the Southeast Alaska Sperm Whale Avoidance Project (SEASWAP) to reduce sperm whale depredation upon demersal longlines in the Gulf of Alaska. One research result has identified the acoustic cue alerting whales to fishing activity as engine cycling. The North Pacific Research Board has enabled testing of a countermeasure that broadcasts engine cycling sounds from a decoy playback device. The goal is to prevent or delay whales from approaching true fishing activity. In summer 2013, 26 trial deployments were conducted on 10 longline sets with whales present. Five of these data sets meet criteria for analysis and bulk processing has started. The remaining five out of 10 were problematic due to an internal clock reset issue. These data were salvageable by matching the fisherman’s notes with the acoustics from the recorders. Preliminary power analysis showed 7-10 sets required for statistical power, which have been achieved. Statistical analysis will be conducted to analyze the proportion of time the fishing hauls were whale-free, with regard to the distance from the set to the decoy device, the time of decoy activation, time of haul, and time whales were first observed at the haul. Whales showed up at the true fishing haul 7 out of the 10 times they were acoustically present in the area or at the decoy device. The number of whales observed at each set ranged from 0 to 3 (mean = 1.1±0.94 SD). Continued analysis will dictate efficacy of this potential deterrent.
Invited Talk: The Right Bycatch Management Tool for the Right Problem: How Catch Shares and Incentive Programs Are Being Utilized and How We Can Do Better

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With the creation of multispecies catch share programs, halibut bycatch reduction efforts in several fisheries, and through actions to reduce Chinook and chum salmon bycatch in the Bering Sea and Gulf of Alaska pollock fisheries, we have seen a variety of new bycatch management programs implemented over the last decade. The nature of the bycatch problem is by no means uniform across fisheries. In some cases, such as with endangered sea turtles or seabirds, the goal is complete avoidance. With salmon and halibut bycatch the goal is avoidance, but there is a trade-off inherent to catching the quota of the target species that permits that some salmon and halibut be taken because of the frequent comingling of the target and bycatch species. In multispecies fisheries such as the BSAI (Bering Sea Aleutian Islands) Amendment 80 fishery and the US West Coast groundfish fishery, scarce species are caught and marketed but are also avoided as vessels attempt to maximize multispecies revenue while not exceeding limits for species with more restricted quotas.

Because of these different management objectives and legal requirements, there is no “one size fits all” mechanism. Biological, economic, and other institutional factors such as industry organization and observer coverage all impact how bycatch management programs function. We discuss how these factors determine which mechanisms appear to be most effective at addressing different problems. As well as presenting a framework for how incentives impact fisher behavior and bycatch outcomes, empirical examples from a variety of Alaska and other US fisheries are provided.
Managing bycatch and targeted catch through common-pool quotas can often result in a “race to fish,” leading to biological and economic waste. Incentive-based approaches—such as individual bycatch quotas and harvester cooperatives—have been proposed as viable management alternatives to address the fisheries bycatch problem. Such approaches, however, rely on fishermen’s ability to adjust their catch composition to avoid bycatch species. We characterize the extent of bycatch avoidance before and after the introduction of incentive-based management in the Bering Sea Aleutian Islands (BSAI) non-pollock groundfish trawl fishery in 2008. Prior to 2008, the BSAI groundfish fishery managed the incidental bycatch of Pacific halibut through a fleet-wide common-pool total allowable catch (TAC). Due to the complementary role halibut plays in the catch of targeted species, a binding TAC for halibut often resulted in the premature closure of target fisheries, leaving millions of dollars of unharvested target species quota on the table. In 2008, the North Pacific Fisheries Management Council rationalized the BSAI groundfish fishery under Amendment 80 (A80). Under A80, shares of the TACs for several target and bycatch species are allocated to individual fishermen that are vested in either a cooperative formed by participating members or in a limited access common pool fishery. We find that fishermen are remarkably capable of adjusting their catch composition under the new incentives in A80, suggesting that fishing technologies may be far more flexible and selective than is often predicted from data gathered prior to a policy change.
The Importance of Location and Timing of Fishing Effort for Bycatch Avoidance in the BSAI Non-Pollock Groundfish Trawl Fishery

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Incentive-based management approaches—such as individual bycatch quotas and harvester cooperatives—have been proposed as viable management alternatives to address the fisheries bycatch problem. Such approaches, however, rely on fishermen’s ability to adjust their catch composition to avoid bycatch species. In 2008, the North Pacific Fisheries Management Council adopted incentive-based management for the Bering Sea Aleutian Islands (BSAI) non-pollock groundfish trawl fishery through Amendment 80 (A80). Under A80, shares of the TACs for several target and bycatch species are allocated to individual fishermen and then either vested in a cooperative formed by participating members or in a limited access common pool fishery. Vessels in A80 cooperatives have demonstrated much greater selectivity between bycatch (halibut) and target species in this bottom-trawl fishery than was apparent before 2008. A natural question in light of these changes is “how?”

This research draws upon haul-level observer data and interviews to examine the mechanisms for this flexibility. We find three primary mechanisms for the dramatic reductions in halibut bycatch. First, captains proactively shifted their effort away from areas with high bycatch to target ratios. Second, captains were much quicker to move away from bycatch “hotspots” after A80 than before. Third, the allocation of fishing time between night and day shifted away from nighttime hours to take advantage of differential diel behaviors of bycatch and target species. Each of these mechanisms was common-knowledge to captains prior to A80 implementation, but they were not adopted due to the lack of individual incentives for bycatch avoidance under the old form of management.
Proactive Management and Reactive Regulations: Accounting for Bycatch in the US Sea Scallop Fishery

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Management of US marine fisheries, based on Annual Catch Limits as output controls for all fish stocks, recently incorporated Accountability Measures (AMs) to ensure catch limits are not exceeded. The interpretation of AMs varies widely from coast to coast and has been applied differently among the eight regional fishery management councils. In the New England region, AMs consist of payback measures or fishery closures and have been applied broadly to bycatch species. The Atlantic sea scallop fishery management plan includes AMs for the bycatch of yellowtail and windowpane flounder, stocks of low monetary value compared to scallops, which are not currently targeted in the scallop fishery. If triggered, the flounder AMs force closure of large areas of prime scallop grounds. These reactive measures ignore socioeconomic incentives to reduce bycatch through altered fishing behavior. The narrow focus on punitive AMs, rather than proactive and preventative measures increases the likelihood that catch limits could be exceeded regularly, with minimal conservation benefit to the flounder stocks and large economic costs to the scallop fishery. However, reactive regulations may incentivize proactive approaches to managing bycatch. Innovative measures for voluntary bycatch avoidance, such as real-time communications and gear modifications could be expanded to achieve both the conservation and socioeconomic goals of the fishery. This case study examines the roles of science, management, and industry stakeholders in determining AMs for the flounder stocks, focusing on successful strategies and persistent problems.
Management Approaches to Improve Target Catches under Reduced Pacific Halibut Bycatch Limits

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US managers are revising management of Pacific halibut bycatch limits for groundfish fisheries in the Gulf of Alaska (GOA) in two steps. Step one reduced the halibut bycatch limit for the groundfish trawl gear sector (from 1,973 t to 1,706 t) and groundfish catcher vessel hook-and-line gear sector by 15%. The reduction will be phased in over three years: 7% in 2014, an additional 5% in 2015, and an additional 3% in 2016. The reduction for the catcher processor hook and line gear sector is 7% in 2014. In total, the allocation will be reduced from 290 t to 256 t. Previously higher halibut bycatch limits have resulted in the closure of specific groundfish fisheries prior to the fleet harvesting the available TAC. Annual first wholesale gross revenue is expected to increase about $2.3 M for the commercial halibut fisheries, while the commercial groundfish fisheries were estimated to experience losses of approximately $10 M annually by 2016, without the tools necessary to mitigate potential reductions in groundfish target catch resulting from reduced bycatch limits.

Step two involves consideration of management tools to improve incentives for bycatch reduction and management of halibut in commercial trawl fisheries for groundfish, along with previously rationalized fisheries, in three GOA management areas. A share-based cooperative system would be the basis for the industry management tools. Results of preliminary analyses on the status of groundfish, halibut, and salmon stocks, and potential effects on the commercial fishing sectors and coastal communities, will be presented.
Evaluating Common Pools to Mitigate Shutdown and Market Risk in Fishing Quota Markets with Stochastic Bycatch

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Individual transferable quota systems are being used to manage bycatch in many fisheries, but in some cases bycatch rates are highly stochastic, making it hard for users to predict their quota needs. In the West Coast US groundfish fishery, some rockfish species have quotas averaging less than one fish per vessel, and are encountered randomly (with little ability to avoid) on 2-5% of trips. Many harvesters will not encounter one during a year, but a harvester who encounters one early faces significant shutdown risk or quota cost. Harvesters in this fishery have, paradoxically, chosen to create a common pool of their individually allocated quota for these limiting species, rather than face market risk for buying quota if they need it.

We explore conditions under which quota holders might prefer this “risk pool” arrangement, using simulations to demonstrate a framework that predicts profit risk based on the predictability of bycatch levels, the quantity of bycatch quota, and the ability of harvesters to avoid bycatch. We behaviorally test the model with a novel quasi-continuous experimental common pool environment, in which subjects play the role of fishermen in a two-species fishery, choosing whether to fish in each week of a 52-week fishing season with a contemporaneous price externality and a time-varying probability of encountering a limiting species. We find risk pools can improve outcomes over quota markets for infrequently encountered and severely limiting species, particularly if harvesters are uncertainty averse, or able to even slightly improve on Nash outcomes for pooled quota.
The West Coast groundfish fishery transitioned to an individual fishing quota (IFQ) system in January 2011. Under IFQs, a specific form of catch shares, fishers are allocated a fixed share of the total allowable catch (TAC). Theoretically, IFQs should prevent overfishing while increasing economic efficiency fleet-wide and promoting better stewardship. In this fishery, onboard government observers monitor catch to prevent overfishing, yet the overall economic effects are not clear. One fundamental issue is the weak stock bycatch problem, in which overfished and rebuilding species are caught incidentally while fishing for target species. Weak stock allocations can be prohibitively low, and one bad trawl may force fishers to cease fishing until additional quota can be leased to cover the deficit. Overall, discard rates have declined substantially for many species since IFQ implementation as expected. Surprisingly, ratios of catch:TAC have declined for all but four species. Fishing effort has shifted as well, potentially to avoid areas of high bycatch or to avoid closed areas of the coast. While IFQs achieve conservation goals, management may need to be further refined to achieve economic goals.
Implementation of a New Bycatch Law (N° 20.625) in Chile

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Current levels of bycatch threaten biodiversity and long-term sustainability of many fisheries worldwide. For Chile, the tenth world fish producer, securing its fisheries represents both strategic and public concern. Between 2004 and 2010, landings declined 45%, and recent evaluations of its main fisheries revealed alarming facts: 15 fully exploited, 10 overexploited (5 at risk of collapse), and 3 collapsed. To reverse this situation, the Fisheries Law was amended, enhancing the focus on conservation and incorporating the ecosystem approach and precautionary principle. Additionally, a bycatch Law was enacted in 2012. This law establishes control measures and sanctions for those who discard, and improves working conditions for fisheries observers, ensuring the collection of unbiased data.

Since bycatch data weren’t collected in the past, a two-year research program has been required to gather basic information. The program started with five bottom-trawl fisheries, but will be expanded in 2014. Participating vessels were exempted from bycatch penalties to discourage unusual fishing behaviors. Within three years, a reduction plan, containing technological and administrative measures, surveillance programs, and incentives to improve selectivity, will be established. Release of mammals, turtles, and seabirds is mandatory. When severely injured they must be taken to rehabilitation centers. Discarding some species will be mandatory. As of 2014, vessels are required to inform amounts discarded, and (on vessels ≥45 feet) install electronic monitoring systems to detect discarding (observers cannot monitor compliance). To gain fishermen’s collaboration and reduce the program interference, prior to data collection workshops were held to socialize the law, sensitize users, and adapt sampling methodologies.
Among fishery bycatch issues in the North Pacific, Pacific halibut has the longest history and has been the subject of a never-ending debate among fishers and managers since the 1960s. The loss to the resource and directed fishery are obvious, and the costs to the capture fisheries are equally apparent. Bycatch controls were straightforward from the 1960s to mid-1970s, when the groundfish fisheries were prosecuted by foreign nations and bilateral agreements mandated “just take less” or “don’t fish in this area.” The evolution to joint venture fishing in the late 1970s and early 1980s began the gradual change from very strict bycatch controls to less strict controls applied to purely domestic fisheries. Since 1990, the issue has pitched neighbor against neighbor. Bycatch has declined over the past 20 years, yet the proportion of total removals accounted for by bycatch has increased. Substantial reductions have been achieved in two jurisdictions through the adoption of individual bycatch quotas in trawl fisheries, but similar progress has not been achieved in Alaska. Pressure for management measures to reduce bycatch is coming from both within the Alaska industry and externally. Viable and immediate solutions are available that would enable reductions with minimal cost to the industry. However, it is uncertain when or whether Alaska managers will provide the regulatory tools that have been successful elsewhere. In the long term, industry demands for such tools may be the key factor in resolving halibut bycatch.
Invited Talk: Developing Effective Solutions to Bycatch in Alaska through Cooperative Research: Gear Modifications to Reduce Pacific Halibut Bycatch in Sole and Cod Fisheries of the Bering Sea and Gulf of Alaska

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My talk will begin by introducing case studies of cooperative research to develop effective ways to reduce bycatch. I will encourage the audience to think beyond just the innovativeness of the solutions in the context of bycatch problems/issues addressed. I will ask them to think about the key ingredients to success common to the case studies. This will include elements such as: degree to which fishermen's knowledge and experience was critical to development of each solution; how the collaboration between scientists/managers and fishermen was structured; institutional arrangements for funding/design work and field testing; iterative process used for testing and design development; and addressing up front how the bycatch solution would be implemented into the fishery. Next, I will lead off the case studies with a description of the development of modifications to flatfish and cod trawls to reduce halibut bycatch in Alaska from 1998 to present. This will describe the initial, somewhat ad hoc efforts by fishermen and how these were improved by entering into a collaborative process (both within the industry and with scientists at the Alaska Fishery Science Center). This collaboration led to a productive sharing of design concepts between fishermen and gear manufacturers and between fishermen and scientists. It also eventually led to the incorporation of systematic testing methods. Finally, success was achieved through usage of technologies such as NOAA's underwater cameras and recording sonar systems, which improved understanding of excluder and net shape parameters and showed how differences in fish behavior create opportunities for effective selectivity.
Significant Reductions in Mortality of Threatened Seabirds in a South Africa Trawl Fishery

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Globally, many thousands of seabirds are killed accidentally in demersal trawl fisheries through cable interactions and net entanglements. However, multiyear data sets for estimating seabird-trawl interactions robustly are scarce. An estimated 9,300 seabirds were killed annually through cable strikes in the South African deep-sea hake trawl fishery birds in 2004, of which about 7,200 were albatrosses. We compare this to new data from 2006-2010 for wet-fish vessels using a single measure (bird scaring lines, BSLs) to reduce seabird mortality. From 64 trips and 690 hours of observation, 41 seabirds were observed killed due to cable strikes, of which 22% were albatrosses. Fatal cable interactions occurred overwhelmingly when vessels discarded offal, with the highest rates (birds killed per hour of observation, b/hr) in winter and during setting. Comparing rates shows that bird scaring lines alone resulted in 73-95% lower mortality in the winter/discard strata (all seabirds: 0.56 birds/h before, 0.15 birds/h after, \( P < 0.001 \); albatrosses: 0.44 birds/h before, 0.02 birds/h after, \( P < 0.001 \)). Estimated total mortality (mean and 95% CIs) in this fishery in 2010 was 990 (556-1,633) seabirds, including 83 (38-166) albatrosses, a reduction in albatross deaths of almost 99%, reflecting both bird scaring line effectiveness and reduced annual fishing effort from 2004-05 to 2010. Our results demonstrate that when government institutions and fishing industries act according to scientific advice, e.g., through adoption of mandatory bycatch mitigation measures, positive impacts can be significant.
Developing a Salmon Excluder for the Pollock Fishery

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In 2003 Bering Sea fishermen became interested in a bycatch reduction device (BRD) for reducing Chinook and chum salmon bycatch. Gulf of Alaska pollock fishermen joined this effort in 2012.

At the start there was little information regarding salmon behavior in pollock trawls, nor any BRD designs for salmon escapement based on behavioral differences between the two species alone. Armed with a short video of salmon swimming out of a hole cut in a pollock net and a blank whiteboard, industry managers, fishermen, vessel owners, net designers, and NMFS scientists with experience in fish behavior/gear modification brainstormed to produce a “salmon excluder” concept. The design was intended to: (1) allow salmon to escape without injury, (2) be readily adopted into fishery, (3) minimize pollock escapement, (4) be reasonably affordable and practical from a gear usage/maintenance perspective.

A cooperative research effort between the pollock industry and NMFS Alaska Region’s RACE Division was begun in 2003. The North Pacific Fishery Research Foundation has served as a coordinator for the pollock industry’s work on this project since the outset, spearheading a series of exempted fishing permits and flume tank research trips. Combining tank research, field testing, and input from fishermen has resulted in several generations of excluder designs incorporating different ways to create salmon escapement. This evolutionary process, starting from an untested concept and culminating in the eventual achievement of a useable excluder, involved numerous successes and failures, each of which contributed immeasurably to the success of the project.
The US West Coast limited entry (LE) groundfish trawl fishery is managed under a catch share program and operates under annual catch limits and individual fishing quotas along with individual bycatch quotas (IBQs) for prohibited species. For many fishermen participating in the bottom trawl component of this fishery, bycatch of Pacific halibut is a concern because limited IBQ is available. Individual fishermen could reach their Pacific halibut IBQ before reaching their catch share quota of healthier stocks, thereby ending their fishing season or forcing them to purchase limited and expensive quota. In this study, we examined two industry-designed Pacific halibut flexible sorting grid bycatch reduction devices (BRDs): one was developed for use in the deepwater Dover sole/thornyhead/sablefish (DTS) complex fishery, while the second was developed for use in the nearshore directed flatfish fishery. Fish retention (by weight) was quantified using a recapture net. For the BRD tested in the DTS fishery, retention of marketable-sized Dover sole, thornyheads, and sablefish was 99.0%, 96.9%, and 90.0% respectively. Pacific halibut bycatch was reduced by 83.7%. In the nearshore directed flatfish fishery, the BRD examined retained 85.1% of the marketable-sized flatfishes encountered. Retention was highest for petrale sole (93.3%), and Dover sole (89.4%). Bycatch of Pacific halibut was reduced by 93.7%, while catches of rockfishes and roundfishes were reduced by 72.1% and 96.5%, respectively. Results demonstrated the capability of flexible sorting grids to improve trawl selectivity in the US West Coast LE groundfish bottom trawl fishery while maintaining catches for several target species.
Reducing Unobserved Crab Mortality from Bering Sea Bottom Trawling through Cooperative Research

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The mortality of crabs encountering bottom trawls has long influenced management of both Bering Sea groundfish and crab fisheries. Using research funding from the North Pacific Research Board we were able to provide estimates of mortality rates for crabs that encounter, but escape, trawls. We demonstrate how this unobserved mortality can be reduced by doing three simple things: (1) increasing the diameter of the footrope roller gear; (2) increasing the distance between individual rollers on the footrope; (3) slightly raising the trawl sweeps off the seafloor. These raised sweeps were developed to reduce effects on structure-forming seafloor organisms. During these NPRB projects we worked cooperatively with the Bering Sea flatfish industry to ensure practicality and relevance to their commercial fishery. We estimated escape mortality for crab and escape rates for commercial fish species using auxiliary nets fished behind the sweeps and the footrope and a validated reflex action mortality predictor (RAMP) for *Chionoecetes* spp. The tested gear modifications reduced unobserved crab mortality by approximately three-quarters. The raised sweep modification was put into regulation in 2011 by the North Pacific Fishery Management Council with full support of the flatfish industry. Bering Sea bottom trawl fishermen have voluntarily adopted footropes with larger bobbins and wider spacing, and our research showed that this configuration reduced unobserved mortality of crabs. This research could not have been done without working cooperatively with the Bering Sea flatfish industry and gear manufacturers and it demonstrates the value of cooperative research.
Excess Fish Exclusion Device: Passive System Releases Fish at Depth During Trawling

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Historically high populations of Atlantic cod in the Barents Sea are currently leading to excessively large trawl catches. This leads to reduced quality when the catch exceeds vessel production capacity, increased risk of discarding, gear damage, and safety concerns. Therefore, at the request of the industry and managers, a passive system was developed to limit maximum catch size.

The Excess Fish Exclusion Device (Exfed) consists of a fish lock just behind a rectangular hole in the upper trawl panel covered by a mat attached only at its leading edge. The fish lock prevents the targeted quantity of fish from escaping during haul back. Initially, the mat lies against the top panel of the trawl sealing the hole. As fish accumulate and fill up to the fish lock, water flow is diverted out the hole, lifting the mat and allowing excess fish to escape at the fishing depth. The system is mounted at a distance from the cod line to achieve the target size catch for the vessel.

Six Norwegian vessels were given approval by the authorities to use the system during commercial fishing in 2013. The system design was improved based on feedback from the commercial fleet and gear researchers. Based on their success to date, industry, managers, and researchers have agreed to further develop and test the system in additional trawl designs on additional commercial vessels during commercial fishing in 2014.
Using GIS Data in Real Time to Avoid Bycatch

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With funding provided by the National Fisheries and Wildlife Foundation, the Shorebased Whiting Cooperative (SWC) contracted with Sea State to develop a website that would provide detailed maps of high bycatch events in the whiting fishery. When an SWC member vessel makes a whiting delivery, the data from the National Marine Fisheries Service (NMFS) are entered into an electronic fish ticket database by Sea State, SWC’s catch monitor. Coop members provide Sea State with login identifications and passwords to their confidential catch data on the NMFS website.

Sharing access to these data is the backbone of SWC’s catch accounting and bycatch avoidance compliance program. Members also provide waivers allowing Sea State access to the Vessel Monitoring System satellite tracking data. By combining the two data streams, Sea State is able to produce maps of tows where bycatch was encountered. When a high bycatch tow occurs (one with a rate above the pro-rata base rate established by the coop rules) an email alert is automatically generated and sent out to all coop members with the vessel name, date, and bycatch rate. The alert also contains a link to the “Whiting Bycatch VMS Maps” web page where members can view an interactive map of that tow. The map provides bathymetry and the latitude/longitude coordinates of the tow as well as overlays of navigational charts and closure areas established by the coop. By clicking on the trackline, the user can see a popup with the catch and bycatch amounts and rates.
The Marine Stewardship Council (MSC) is an independent, third-party, nonprofit global organization, founded in 1997, which sets an international standard for sustainable fishing. MSC uses its ecolabel and fishery certification program to encourage fisheries to become more sustainable and rewards these fisheries, when certified, with the ability to use the MSC ecolabel.

Three main principles make up the MSC standard: principle 2 on environmental impacts includes performance indicators (PIs) for assessment of the status, management, and information of bycatch and endangered, threatened, and protected (ETP) species. Each PI is scored on a 1-100 scale, with 60, 80, and 100 defining the key sustainability benchmarks “minimum acceptable limit,” “global best practice,” and “near perfect” respectively. To pass an assessment, a fishery cannot score less than 60 on any one PI and the aggregate score for each principle must be greater than or equal to 80. Further, any PI that scores less than 80 must be improved to the 80 level over the course of the fisheries’ certification (5 years) by triggering an “action plan” to improve the fishery to the level of “best practice.” Since its inception, 36 certified fisheries in the MSC program have shown improvements in bycatch and ETP PIs to achieve best practice level. As of 1 January 2014, this has resulted in 61 completed action plans in these fisheries. Most of the improvements have related to the collection of information and better understanding of the fishery impacts on bycatch and ETP species.
The Development and Deployment of a Real-Time Electronic Bycatch Reporting Solution for the Northeast US Scallop Fleet

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In order to collect higher quality fishery-dependent data, the northeast US limited access scallop fleet needed to develop a real-time electronic bycatch monitoring and reporting system. The objective of this system is to have the fishermen report their bycatch and scallop catch electronically in real time to a central database. These data will then be anonymized and made available to the entire fleet in order to alert the fishermen to hot-spot areas of high bycatch to scallop meat catch ratios. This would allow fishermen to make informed decisions regarding where to fish in order to avoid or reduce bycatch, and possibly a premature closing of the fishery. Olrac SPS, a South African company, was contracted by the Coonamessett Farm Foundation on behalf the northeast US scallop fleet to develop such a software tool. This was an iterative process, incorporating suggestions from the CFF staff, scallop industry representatives, and components from paper logbook forms. The final product was delivered by the end of 2012. It included two components: (a) a GIS-based vessel unit, used to record data and send reports to the shore and (b) a web-based shore unit, used to aggregate and analyze reports sent from the vessel units and to transmit aggregated bycatch ratio density maps back to the fleet. This allows a vessel to view the bycatch ratio density map on their Olrac GIS system and avoid areas of high bycatch. The system is now fully operational and is used onboard 10 vessels as a pilot project.
A Study of Golden King Crab Commercial Fishing Gear Selectivity in the Aleutian Islands After Crab Rationalization
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One intended benefit of the Bering Sea/Aleutian Islands Crab Rationalization Program instituted in 2005 was to reduce bycatch. In the Aleutian Islands golden king crab *Lithodes aequispinus* commercial fishery, a reduction in the bycatch of sublegal-sized male and female crab relative to the catch of legal-sized (≥6.5 inch carapace width) males has, in fact, occurred since rationalization of the fishery. It has been suggested that changes in the design and prolonged soak times of the pot-fishing gear used in the fishery since rationalization are responsible for the reduction in bycatch. The Alaska Department of Fish and Game performed a study in cooperation with commercial fishers during the 2012-13 commercial fishery season to estimate the size-selectivity of male golden king crab by pot-fishing gear as it is currently used in the commercial fishery. Catch data on golden king crab were obtained from 31 pairs of small-mesh research pots and commercial fishing pots fished in the same longlined strings during normal commercial fishing operations. The difference in the catch of legal-sized males was not statistically significant (*P* > 0.05) between research pots (1,378) and commercial pots (1,172), but the greater catch of sublegal-sized males and females by research pots (4,761) than by commercial pots (591) was statistically significant. We fit a logistic function size-selectivity curve for the male golden king crab captured by commercial pots, and our estimate of the size at which 50% of males are retained by the commercial pots was equivalent to the minimum legal carapace width for males in the commercial fishery.
Penaeus indicus and Metapenaeus monoceros are the main shrimp species caught in the Mozambican coast in Sofala Bank. Bycatch fish species in the shallow water shrimp fishery are Otolithes ruber (croaker), Johnius amblycephalus (croaker), Johnius dussumieri (croaker), Pomadasys maculatum (grunt), Trichiurus lepturus (largehead hairtail), Pellona ditchela (Indian sardine), Thryssa vitrirostris (orangemouth thryssa), and Arius dussumieri (blacktip sea catfish); crustaceans are small shrimps and Brachyura crab; and cephalopods include Loligo sp. (squids) and Sepia sp. (cuttlefish). Shallow water shrimp is caught by three different sectors: an artisanal fishery and semi-industrial and industrial fleets that operate to 60 m depth. The three sectors explore the stocks of the two main species, Penaeus indicus and Metapenaeus monoceros. Less abundant species such as P. japonicus, P. monodon, and P. latisulcatus are caught by the industrial fleet when they fish in deeper waters.

The fleets operating in the shallow water shrimp fishery are national and joint venture. The semi-industrial fleet operate in two areas, one near Angoche and the other south of Beira (Dondo and Machanga), both of them are composed of national companies. During 2012, 14 ice semi-industrial vessels operated south of Beira. In 2012 in the industrial fleet the number of vessels (including the freezing semi-industrial) in the shrimp fishery was 57, compared with 50 in 2011. This talk summarizes the available knowledge of shallow water shrimp bycatch regarding species composition, total catch and discard estimates, and biological characteristics of the main species.
The Western Steller sea lion (*Eumetopias jubatus*, SSL) population declined by 80% during the last 30-40 years. Bycatch in the groundfish fishery is hypothesized as one of plausible causes. We used personal interviews with fishermen to evaluate the role of bycatch in the SSL population decline. The major difficulty in our research was an absence of regular observations of bycatch in the western Bering Sea and the patchy data regarding fishing effort in the region. Estimation of SSL bycatch per single fishing effort was calculated based on fisherman interviews and few direct measurements in the 1990s and 2000s. Data on fishing effort were derived from several unrelated sources including fishery reports, archives, and published literature. Fishermen confirmed that SSL bycatch have occurred and continue to occur in the trawl and seine net fisheries. The bycatch level varied from 2-3 individual SSLs per 3-4 month fishing trip up to more than 20 per single tow. Although the population of SSLs in the Russian part of western Bering Sea is about 40 times less than in the 1980s, bycatch still occurs there. Considering past and present SSL bycatch, fishing effort, and SSL long distance seasonal migrations we concluded that bycatch in the western Bering Sea could contribute to the Western population decline. The greatest obstacle in assessing the level of bycatch, and developing recommendations on reduction, is the absence of independent observations from fishing vessels and the unwillingness of fishing companies to recognize this problem.
Balearic Shearwater and Fisheries: Is Bycatch an Issue?

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(Ed Melvin, presenter)

The Balearic shearwater *Puffinus mauretanicus* is the most threatened seabird in Europe, with a relatively small population (>3,000 breeding pairs) in rapid decline (estimated at 7.4% per year). Several recent research and conservation programs from different countries (Spain, Portugal, France, UK, and Ireland) brought new information about the population status, behavior, and threats of the species. Specific research on fisheries (observers onboard and questionnaires to fishermen), mainly through the Interreg program FAME and the Life+ project INDEMARES, showed that bycatch is a big issue for the species in both the Mediterranean (Spain) and the Atlantic area (Spain, Portugal, and France). In Portugal, from 1 to 13% of interviews reported bycatch of Balearic shearwater, depending from the fishing gear and the size of the boat. In France more than 40% of interviewed recreational fishermen (60% from professionals) declared having already caught seabirds including shearwaters. In Spain, shearwaters were often reported, including several events of “mass mortality” affecting tens of Balearic shearwaters, most frequently in Mediterranean demersal longliners. Overall, these preliminary results suggest that Mediterranean bycatch mainly occur in longlining, whereas purse-seiners and trawlers could capture more birds in the Northeast Atlantic. However, further work is required in order to get quantitative information on Balearic shearwater bycatch rates on a more representative fleet and also to test potential mitigation measures and implement the most relevant ones.
Diving Behavior of White-Chinned Petrels and Its Relevance for Mitigating Longline Bycatch [canceled]

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South African waters support large fleets of both foreign and local pelagic longline vessels, targeting tuna and swordfish respectively. Large numbers of seabirds are killed each year while scavenging for bait and offal from these vessels. Seabirds are killed by longline vessels when they swallow baited hooks and consequently drown. In this paper I will look at trends and patterns in the seabird mortalities data from both the autopsied seabird database and the fisheries-collected bycatch database. These databases were both analyzed for the period 1998-2005, and it will be important to understand if trends and patterns in the data have changed. Both operational and environmental factors will be investigated. Some of the factors to be investigated are vessel flag, observer identification, vessel identification, area, season, month, bait type, bathymetry, time of commencement, moon phase, and use of mitigation measures. These data will be important for the creation of future fisheries bycatch legislation.
Stock Composition Estimates of Chinook Salmon Incidentally Taken as Bycatch in the 2012 Bering Sea and Gulf of Alaska Trawl Fisheries

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The Bering Sea and the Gulf of Alaska (GOA) are known feeding habitats for multiple brood years of Chinook salmon (*Oncorhynchus tshawytscha*) originating from North America and Asia. Determining the geographic origin and stock composition of salmon caught in federally managed fisheries is essential to understanding whether fisheries management could address conservation concerns. Changes implemented through Amendment 91 to the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Island Management Area (BSAI) made possible the systematic random sampling of the BSAI salmon bycatch starting in 2011. Samples from the 2012 BSAI walleye pollock (*Gadus chalcogrammus*) trawl fishery were genotyped for 43 single nucleotide polymorphism DNA markers. Coastal Western Alaska stocks dominated (63%) in the analysis of 1,111 Chinook bycatch samples collected throughout the 2012 BSAI walleye pollock trawl fishery. Genetic samples were also collected from Chinook salmon taken in the bycatch of the 2012 GOA pollock trawl fisheries. Genetic samples were collected opportunistically in the GOA during 2012; consequently, the resulting stock composition estimates should be considered as stock compositions of the sample set. Based on the analysis of 948 Chinook salmon bycatch samples, British Columbia (49%), West Coast U.S. Coast (28%), and Coastal Southeast Alaska (20%) stocks made up the largest stock groups. Stock composition estimates of Chinook salmon from tests of salmon excluder devices performed in February 2012 in an area north of Unimak Pass in the Bering Sea showed that the majority of the 249 Chinook salmon collected originated from Coastal Western Alaska (69%).
Chum salmon are accidently caught in the Bering Sea pollock fishery. Low chum salmon returns to western Alaska rivers in some years have disrupted the salmon fisheries in this region and led to concern about the impact of bycatch on chum salmon stocks. Recently implemented regulatory changes in monitoring salmon bycatch through a census in the Bering Sea pollock fishery, 100% observer coverage for each vessel, and an expanded biological sampling program improves our ability to measure the impact of the pollock fishery on salmon stocks. Genetic analysis of chum salmon bycatch samples collected from the 2012 Bering Sea walleye pollock trawl fishery was undertaken to determine stock composition estimates. Evaluation of sampling based on time, location, and vessel indicated that the genetic samples were representative of the total bycatch. The systematic sampling reduces biases in stock composition estimates when applied to the whole bycatch. Samples were genotyped for 11 microsatellite markers and stock contributions were estimated using the current chum salmon microsatellite baseline. As in previous years, the largest contribution was from Asia (59%), followed by the eastern Gulf of Alaska–Pacific Northwest (18%), western Alaska (14%), upper-middle Yukon (7%), and southwest Alaska (2%) regions. In 2012, spatial and temporal changes of regional stock contributions were observed. Genetic analyses of chum salmon samples from a salmon excluder device included chum salmon from across the range of the species despite being collected at small spatial and temporal scales.
Initiatives of Landing Discarded Bycatch from Commercial Shrimp Trawlers in a Social, Economic, and Environmental Feasible Manner: The Case of Sofala Bank, Mozambique

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Shrimp trawling generates enormous amount of bycatch of low economic value that ends up discarded at sea in most commercial shrimp fisheries worldwide. While this bycatch is needed to support food security efforts and generate income in coastal areas it has always been a challenge for governments and the fishing industry to efficiently land those bycatch fish products. This study presents a case study of a bycatch collection informal program carried out by small-scale entrepreneurs in Mozambique’s Sofala Bank coastline and proposes ways to maximize its socioeconomic and environmental benefits. Both biological samples and interview-based information were obtained in five major landing sites located across the 450 nm coastline of the fishery during the 2012 shrimp fishing season. The results indicate that a total of 505 informal collectors operating on average 68 boats (28 motor boats and 40 sail) participate in the collection activity. Each trip to sea lasts up to 9 hours and traveling up to 102 km offshore to purchase from the industrial trawlers bycatch fish through exchange with money or agricultural products. The business generates over 4,000 t of fish per season and revenues on the order of 153,000 USD. A non-metric multidimensional scaling (MDS) analysis carried out for exploring similarities or dissimilarities in the composition of fish taxa landed with that actually caught shows a clear separation between the compositions caught and landed, indicating some fish selection. The landings represent only 10% of estimated bycatch from the Sofala Bank shrimp fishery; therefore there is still room for expansion of the activity. There are difficulties faced by this informal system, whose solutions for maximization and optimization of the socioeconomic and environmental benefits are proposed in this work.
In spite of its fish wealth, Mauritania is not yet food auto-sufficient. The contribution of the fishing sector still small. The majority of the landed captures are commercialized as whole products or in blocks without any valuation and the products of high added value still undeveloped. The wasting of the resources is important and limits the possibilities to reach the national objectives in terms of employment, added value, and food safety. The waste of the resource is principally caused by bycatch and discards and the lack of valuation. In a context of overexploitation of the stocks and in order to increase fish availability for the population, it is important to fully utilize the harvested resource by minimizing post-harvest losses. This talk focuses on the problem of wasting resource in Mauritania. It describes post harvest in Mauritania (activities and actors), tries to highlight the losses and waste of the resource occurring along the post-harvest chain in Mauritania, identifies causes of these losses, and gives some possible ways to prevent them.
Monitoring Bycatch/Discards in the Pacific Halibut (*Hippoglossus stenolepis*) Fishery in Southeast Alaska

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The Individual Fishing Quota (IFQ) program for Pacific halibut (*Hippoglossus stenolepis*) in Alaska is one of the oldest and most well-documented commercial fisheries catch share management plans in the world. Implementation of the IFQ program throughout Alaska has made monitoring catches and offloads of the target species (halibut) highly transparent. However, monitoring bycatch/discards remains a persistent challenge. Halibut fishermen in Southeast Alaska have voiced negative opinions about recent reforms to the federal observer program. Some fisheries groups have proposed that electronic monitoring be allowed as an alternative to human observers, especially on vessels under 57.5 feet long. A third monitoring option is for fishermen to self-report their bycatch/discards in logbooks.

My goal is to determine how Pacific halibut fishermen in Southeast Alaska understand the bycatch/discards problem in their fishery. Primary objectives include (A) document perceptions and opinions of fishermen about monitoring of bycatch/discards; (B) document ability of fishermen to differentiate between common bycatch/discards species; and (C) determine effects of three types of bycatch/discards monitoring on viable fleet composition. My methods build on research focused on integrating local fisheries knowledge into management strategies. This research exploring observations and perceptions of commercial fishermen is timely and important, as it (a) gathers crucial data of interest to fisheries managers; and (b) bridges gaps between fishermen and scientists through their direct involvement in research. Findings will shed light on how fishermen understand bycatch/discards, and these understandings have the potential to inform science and management.
The US shore-based Pacific whiting (Merluccius productus) mid-water trawl fishery is a high volume spring/summer fishery operating off the coasts of Washington, Oregon, and northern California, consisting of about 35 vessels making day fishing trips. Total removals are estimated from landed catch and no discards are permitted. Full retention regulations were monitored from 2004 to 2010 using electronic monitoring, with each vessel equipped with closed circuit television cameras, GPS, winch, and hydraulic sensors. Early monitoring results provided a clearer understanding of fishing practices, providing a framework of more practical regulations on permissible levels of “operational discarding.” The increased transparency provided by the EM program and other factors resulted in a significant decline in at-sea discards over the seven year period. In 2005 nearly all vessels discarded, and most discarded 1.5% or more of their catch. By 2010, a third of the fleet had no observed discards, and among those vessels with discards all but three discarded less than 0.6% of their total catch. The data-rich vessel-specific information system provided by the EM program was instrumental in driving this change in the fishery. The program was co-funded by industry and the National Marine Fisheries Service, and the 2007-2010 average annual cost was $6.03 per metric ton, $254 per sea day, or 3.6% of the landed catch value. Although the EM program significantly improved full retention compliance and the quality of catch data, it was discontinued in 2011 when the groundfish trawl fleet implemented a catch share quota system with 100% observer coverage, funded by NMFS.
Discards Estimate in Bottom Trawl Fishery Squat Lobster (*Pleuroncodes monodon*), First Results of the Discards Research Program in Chile [canceled]

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The amendment to the Chilean Fisheries Law in Chile, during 2013, considered the initiation of a discard research program for fisheries trawl. Through onboard scientific observers, the program aims to estimate total catch and discards of the main species. We show the preliminary results of the squat lobster fishery that operated between April and August 2013, between 21°26’ and 38°28’S. From a total of 316 fishing trips, 33 were monitored to quantify discard. In these trips a total of 170 hauls were realized of which 57 were sampled. We estimated 6,060 t of total catch, of which 15% were discarded. The discarded catch was consisted of 17 species. The weight composition of the discarded catch were mainly composed of bony fishes (92,6 %) and crustaceans (7,3 %), discard the rest corresponded to molluscs and chondrichthians. Compared to similar fisheries in tropical latitudes, where discard rates may exceed 50%, the discard rate in this study was low (15%). Among the main bycatch species, target species for other fisheries such as the Chilean hake, were observed. The results obtained through this research program provides valuable information that should be considered by the fishing authorities for the management of Chilean fisheries from a multispecies perspective, allowing the transition toward an ecosystem approach.
Potential Impacts of Listing Cusk (*Brosme brosme*) as a Federally Protected Species on State Managed Fisheries: What Happens When No One Is in Charge?

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Cusk (*Brosme brosme*) is a National Oceanic and Atmospheric Administration (NOAA) Species of Concern in the Gulf of Maine and Candidate Species throughout its range due to a 75-80% decline in abundance over the past 50 years. In 2007, NOAA initiated a status review to determine if this species should be listed as Threatened or Endangered under the Endangered Species Act (ESA). Three of the four current Candidate Species are finfish that have been petitioned for listing due to population declines from fishing pressure. Cusk is unique in that it is the only Candidate finfish species that is not currently managed by any regulatory agencies. Historically, data-poor species have not been recommended for ESA listing in part because proactive regulatory mechanisms for conservation or rebuilding were in place. The lack of regulatory mechanisms regarding cusk creates uncertainty in how to proceed with conservation measures, such as an ESA listing. Listing cusk could have implications on state fisheries where cusk is common bycatch such as the Maine lobster fishery. Through a review of the literature and existing legal documents and interviews with state, interstate, and federal agencies, this research aims to determine potential regulatory impacts on state-managed fisheries if cusk became federally protected under the ESA. This research will also explore what, if any, proactive regulatory mechanisms could minimize potential impacts.
Artificial Bait in Pelagic Longline Fisheries: Insights from Trials and Research Needed
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For the pelagic longline fisheries (PLF) knowledge of both behavior and distribution of fish for target species (mainly tunas and swordfish) are not sufficient to mitigate: (i) non-sustainable fisheries interactions with endangered, protected, and threatened megafauna and (ii) the impact of fishing pressure on non-managed bycatch species. An indirect impact of PLF on marine ecosystems concerns the removal of marine resources used as bait. Many bait species (squid, mackerel, sardine) might serve as important source of natural protein for direct human consumption. In the meantime, natural bait used in the tuna industry as well as non-processed dead discards and post processing fish remains are source of organic wastes. In the context of the ecosystem approach to fisheries the substitution of natural bait with artificial analogue is a major challenge to be addressed by gear technologists. Such an innovation might alternate the extremely negative perception of pelagic longline gear. Here we present preliminary results from fishing trials undertaken in 2012 with an artificial bait prototype developed for PLF in the EU MADE project. Insights obtained from these first results allow us to define new directions in research to be planned.
Quantifying Habitat Impacts of Raised Ground-Gear for the Bering Sea Pollock Fishery

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In the United States, federally managed fisheries need to minimize both bycatch and the adverse impacts of fishing on essential fish habitat while maintaining commercially viable catch efficiencies of target species. Like many other large-scale commercial fisheries, the Alaska pollock fishery operations are increasingly constrained by efforts to avoid bycatch (salmon, crab, and halibut) and the rising cost of fuel. Under the NPRB-funded project, a research team including both major sectors of the Alaska pollock fishing industry, scientists from the NOAA Alaska Fisheries Science Center and Alaska Pacific University, and members of the fishing gear design and fabrication industry, is working to develop more optimal trawls for capturing pollock near the seafloor. This project addresses the seabed contact and benthic habitat impact aspects of several new ground-gear configurations. Thus far raised ground-gear (sweeps and footrope lifted off the seafloor by widely spaced bobbins) have resulted in reduced direct seafloor contact, reduced crab mortality, and flatfish bycatch, while maintaining pollock fishing performance relative to standard ground-gear. During summer 2014 we will systematically vary bobbin weight, spacing, and seafloor clearance to (1) quantify the component-specific (e.g., sweep, bobbin, footrope) seabed contact; (2) determine susceptibility of structure-forming geological and biological seabed features to these new ground-gears; and (3) compare the contact-adjusted swept areas of, and habitat-feature susceptibilities to, each configuration to support a quantitative evaluation of the new pollock trawl designs within the context of a fishery habitat impacts assessment. This work directly addresses bycatch and essential fish habitat concerns of the North Pacific Fishery Management Council.
US managers have undertaken a series of analyses and regulatory actions to improve management of prohibited species (salmon, Pacific halibut, and crab) in the North Pacific groundfish fisheries. Prohibited species must be avoided in target groundfish fisheries, and must be carefully released in some cases. Attainment of bycatch limits, or their seasonal or fishery sector apportionments, results in closure of the fishery in which that bycatch is taken. Such closures result in economic losses to groundfish fishermen and processors, and to the communities that support these operations. In the absence of limits, bycatch has been managed using time and area closures based upon historical bycatch trends.

A review of recent actions to set or reduce bycatch limits in North Pacific groundfish fisheries compares and contrasts the problems and management solutions identified for each combination of bycatch species and target fishery. These include (1) Chinook salmon in the Bering Sea pollock fishery; (2) chum salmon in the Bering Sea pollock fishery; (3) Chinook salmon in the Gulf of Alaska pollock fishery; (4) Chinook salmon in the Gulf of Alaska non-pollock fishery; (5) Pacific halibut in the Gulf of Alaska groundfish fisheries; (6) Pacific halibut in the BSAI groundfish fisheries; (7) snow crab, Tanner crab, and Bristol Bay red king crab in the eastern Bering Sea groundfish fisheries; and (8) crab in Gulf of Alaska groundfish fisheries.
Bycatch of marine mammals in fishing gear has been a central concern of resource managers, the commercial and recreational fishing industries, conservationists, scientists, lawmakers, and the public both nationally and globally for the past several decades. The US Marine Mammal Protection Act (MMPA) provides a rigorous framework for reducing serious injuries and deaths of marine mammals in commercial fisheries. The MMPA includes both short-term (within 6 months) and long-term (within 5 years) goals and details requirements necessary to attain these goals.

The primary mechanism for achieving these goals is convening a stakeholder-based “take reduction team,” which is tasked with developing recommendations for specific regulatory and voluntary measures designed to reduce bycatch to appropriate levels. Teams submit their recommendations to the NOAA National Marine Fisheries Service, who then evaluates and analyzes those recommendations before undertaking the federal regulatory process.

This poster will provide an overview of the MMPA process for establishing and working with take reduction teams as well as developing, implementing, and monitoring marine mammal take reduction plans. Further, the poster will include valuable lessons learned from convening nine take reduction teams and developing seven take reduction plans since the program’s inception in 1994.
Fishery observers collect valuable information on commercial catches, including bycatch and discards. Observer programs are often intended to provide information on total fishing mortality for catch quota implementation, and help assure compliance with other fishing regulations. However, the value of these data sets, collected at great cost to fishing industries and/or regulatory agencies, extends beyond these management applications. We provide three research examples that made use of underutilized data from fishery observer programs in Alaska. First, using bycatch observations on groundfish trawlers during 1977-2003, we reconstructed monthly distributions of Pacific herring (*Clupea pallasii*) over their 2,100 km–long seasonal migrations in the eastern Bering Sea. This enabled us to develop spawning timing models based on sea ice concentration and ocean temperatures in their pre-spawning habitat. Second, we defined the spatial distribution of Pacific spiny dogfish (*Squalus suckleyi*), a data-poor species in the Gulf of Alaska, based on statistical models of dogfish bycatch taken on longlines by commercial and assessment survey vessels during 1996-2008. Results provided a basis for first-ever designation of essential fish habitat, as well as area-specific information to inform the design of future assessment surveys and at-sea sampling programs. Finally, multivariate analyses of fish and invertebrate bycatch, taken in weathervane scallop (*Patinopecten caurinus*) dredge fisheries during 1996-2012, revealed the biogeography of benthic communities throughout the Gulf of Alaska and eastern Bering Sea, as well as temporal variability that may be related to fishing and climate variability. Fishery observer data harbor a wealth of largely untapped scientific information.
Beginning in 2004, the NOAA Fisheries Northwest Fisheries Science Center (NWFSC) initiated a fisheries conservation engineering program within its Fisheries Resource Analysis and Monitoring Division. Through key regional collaborations with the Pacific States Marine Fisheries Commission, Oregon Department of Fish and Wildlife, Alaska Fisheries Science Center, and the fishing industry, the NWFSC has been able to pursue a wide-ranging array of conservation engineering projects relevant to reducing bycatch in the West Coast groundfish and ocean shrimp trawl fisheries. In the past several years, these projects included (1) reducing Chinook salmon, eulachon, rockfish, and Pacific halibut bycatch in mid-water and bottom trawl fisheries using bycatch reduction devices (BRDs), (2) providing loaner video camera systems to the fishing industry, and (3) examining selectivity characteristics of codends that differ in mesh size and configuration in the bottom trawl fishery. Much of our current work has been in response to the fishing industry’s concerns over catches of overfished rockfishes and Pacific halibut IBQ (Individual Bycatch Quota) allocated in the Pacific coast Groundfish Trawl Rationalization Catch Share Program. The trawl rationalization program, starting in January 2011, established formal Annual Catch Limits (ACLs) and individual catch share quotas. In addition to ACLs, fishing opportunities may also be limited by hard caps or IBQs for non-groundfish species (e.g., Chinook salmon and Pacific halibut). Bycatch of overfished and prohibited species in the West Coast groundfish trawl fishery has the potential to constrain the fishery such that a substantial portion of available harvest may be left in the ocean.
In 2009, ALFA launched a Fishery Conservation Network (FCN). The FCN empowers stewardship innovation by engaging fishermen in research and collaboration. FCN members identify issues of mutual concern, then collaborate to develop tools and information networks to address those concerns. For example, FCN members identified areas with high rockfish bycatch and generated seafloor maps to identify the benthic structures that concentrate rockfish in those areas. In the first three years of mapping and sharing bycatch rate data, FCN members reduced demersal shelf rockfish bycatch on their halibut sets by 20% and slope rockfish bycatch on their sablefish sets by 6%.

The FCN is also engaged in SEASWAP—the Southeast Alaska Sperm Whale Avoidance Project—a powerful collaboration between fishermen and scientists at the University of Alaska, Sitka Sound Science Center, and Scripps Institution of Oceanography. SEASWAP collected the first genetic data on Gulf of Alaska sperm whales; recorded previously unknown data on whale movement and feeding behavior through satellite tagging, underwater photography, and acoustic recordings; and launched ongoing deterrent testing that assists fishermen with avoiding costly and potentially dangerous interactions with sperm whales. With the Central Bering Sea Fishermen’s Association joining SEASWAP in 2010, research has expanded to include Bering Sea killer whales. Other FCN projects include electronic monitoring and improved fuel efficiency for small boats. In sum, the FCN combines fishermen’s innovation with scientific discipline to address complex resource issues and build solutions scaled to meet the needs of community-based fishermen.
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