Evaluating the Quality of Bycatch Data and Bycatch Estimates Among Disparate Fisheries

LISA L. DESFOSSE, WILLIAM A. KARP, and SAMANTHA G. BROOKE

Introduction

Effective management of living marine resources depends on understanding the population dynamics of target and bycatch species and related ecosystem processes. Accurate estimates of catch and bycatch are essential when determining overall mortality and stock status, as well as in establishing effective management strategies.

Lisa L. Desfosse is Director of the Pascagoula Laboratories, Southeast Fisheries Science Center, National Marine Fisheries Service, NOAA, 3209 Frederic Street Pascagoula, MS 39567-4112. William A. Karp is Deputy Director for Science and Research, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way, N.E., Seattle, WA 98115. Samantha G. Brooke is with the Marine National Monuments Program, Pacific Islands Regional Office, National Marine Fisheries Service, NOAA, 1601 Kapiolani Blvd, Suite 1110, Honolulu, HI 96814. Corresponding author is Samantha Brooke (samantha.brooke@noaa.gov).

ABSTRACT—In 2006, the National Marine Fisheries Service, NOAA, initiated development of a national bycatch report that would provide bycatch estimates for U.S. commercial fisheries at the fishery and species levels for fishes, marine mammals, sea turtles, and seabirds. As part of this project, the need to quantify the relative quality of available bycatch data and estimation methods was identified. Working collaboratively with fisheries managers and scientists across the nation, a system of evaluation was developed. Herein we describe the development of this system (the "tier system"), its components, and its application. We also discuss the value of the tier system in allowing fisheries managers to identify research needs and efficiently allocate limited resources toward those areas that will result in the greatest improvement to bycatch data and estimation quality.

While mandatory reporting of all landings is required in most U.S. commercial fisheries, bycatch estimates are typically derived from a variety of data sources, including commercial fisheries observers and self-reported. Bycatch estimation methods also typically vary among fisheries and are dependent on several factors such as temporal and spatial extent of the fishery, quantity and quality of data collected, and the availability of supplemental data. The quality of bycatch data is evaluated during the development and review of species-specific stock assessments in some cases. However, a basis for comparison of the quality of bycatch estimates for different fisheries or species groups is lacking.

The lack of objective criteria makes it difficult to direct resources toward improvements in data collection or analytical methodology, and precludes a process for tracking improvements in this important aspect of the work of the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS). Furthermore, objective information on the quality of bycatch estimates may be used as a basis for including or excluding data when compiling synoptic reports or interpreting global bycatch estimates reported by various authors. Without a method of comparison, recent reports on overall global (Kelleher, 2004) and U.S. (Harrington et al., 2005; Moore et al., 2009) bycatch levels are difficult to interpret because of widely differing information sources and analytical methods.

Many criteria can be used to evaluate the quality of bycatch data in both species-specific stock assessments and in the development of national bycatch estimates. Having a standard set of criteria that can be applied to bycatch estimates from all fisheries will assist in ensuring that high quality bycatch information is used to develop effective management strategies. A standard process may also assist in identifying potential areas of concern with bycatch data collection programs and estimation methods.

This process may also aid fisheries managers in making strategic and financial investments in different data collection programs, particularly when resources are limited. Understanding the quality of bycatch data, as well as of the estimates themselves, is necessary so that scientists, managers, fishermen, and the general public can have confidence in the use of such information as the basis for developing and implementing bycatch management strategies.

The NMFS recently completed the first edition of a new report, the *U.S. National Bycatch Report* (NMFS, 2011). This report documents bycatch estimates and bycatch estimation methods for commercial fisheries for which this information was available in 2005.[1] The report also outlines a new system (referred to as the "tier classification system") for evaluating the bycatch data sources and estimation methods for U.S. commercial fisheries included in the report.

In addition to establishing a baseline for future comparisons of improvements in bycatch estimation, the tier system will help to identify fisheries where improvements in bycatch data collec-

[1] The year 2005 was selected during the report's development in 2006 as the most recent year for which complete information was available; NMFS intends to publish updated information in future editions.

tion and/or estimation are required. This paper provides a review of the tier classification system, results of its use, and describes broader applications for such a system.

Methods

The tier classification system utilizes standardized criteria for evaluating bycatch data collection programs and analytical approaches for estimating bycatch. Individual criteria were developed through a 2007 national workshop with participation from all regional NMFS Fisheries Science Centers and Regional Offices, as well as NMFS headquarters offices. The initial design of the classification system was based on a similar system applied to the evaluation of fish stock assessments (NMFS, 2001), which evaluated the levels of available input data, assessment methodology, and assessment frequency for managed fish stocks.

Criteria selection was based on the identification of critical components required to provide reliable and accurate bycatch estimates. The classification system was tested on several fisheries during the 2007 workshop to ensure that the scoring system worked for the full range of U.S. commercial fisheries.

Description of Criteria

The criteria used in the tier classification system are grouped into four broad categories: adequacy of data, availability of supplemental data, database and information technology (IT) considerations, and analytical methodology. While the first three categories relate primarily to the quality of the bycatch data, the last category is focused on the quality of the resulting bycatch estimate.

Adequacy of Bycatch Data

These criteria involve evaluation of bycatch data collected through observer programs and self-reported logbooks. Since observer programs provide more reliable information than self-reported logbooks (NMFS, 2004), a higher score is assigned for fisheries that had implemented observer coverage to estimate bycatch. Specific criteria for evaluation of observer programs are program longevity, sampling frame and design, and program implementation. Evaluation of vessel selection and observer bias is based on a formal review of bias in NMFS observer programs (Vølstad and Fogarty[2]). Spatial and temporal coverage levels are evaluated as either limited or synoptic based on the geographic and temporal scope of the program. Limited programs were defined to be of a lesser geographic and temporal scope than the scope of the fishery. Self-reported data are scored on the basis of presence or absence. In the majority of cases these data are not evaluated for reliability, thus a detailed evaluation cannot be conducted. These data are instead scored on their concurrence with the time frame of the estimate. Criteria and scores for this category are detailed in Table 1; the total possible score for this section is 35.

Availability of Supplemental Data

Here we consider data used as extrapolation factors for unobserved components of the fishery, for stratification and imputation (the substitution of some value for a missing data point or a missing component of a data point), as model covariates, and to verify self-reported data. Examples include: environmental variables, logbook, or state data. Details are provided in Table 2; the total possible score for this section was 10.

Database and Information Technology Considerations

These factors are evaluated in the context of whether the relationship between systems containing observer data and those holding supplemental data constrains analytical process (i.e., the two types of systems do not share common identifiers or are not linked). Table 3 lists all criteria and point values in this area; the total possible score for this section is three.

Analytical Methodology

Here we consider bycatch estimation method assumptions, peer reviews of analytical methods, statistical bias of estimators, and the availability of uncertainty estimates. Biases associated with the estimators used in the analytical methods are evaluated based on measures of association, cross validation, and other factors. The guidance provided on these criteria is intended to ensure consistency; however, the evaluation and scoring were also based on the in-depth knowledge of the biologists and assessment scientists within each region and are thus, by nature, somewhat subjective. Details are provided in Table 4; the total possible score for this section is 25.

The scoring system for each of these criteria assigns higher scores for higher-quality bycatch data and for more reliable estimation methods. The major criteria are weighted through the scoring system to ensure higher scores for those criteria that are considered to improve the overall quality of bycatch estimates. For example, observer-collected bycatch data are weighted more heavily than self-reported bycatch data because observer data are verified through a quality control process (a total of 33 points are possible for observer data, while a maximum of 2 are awarded for self-reported data).

The majority of the criteria used in the tier classification system are objective. The longevity of observer programs, sampling design characteristics, availability of industry and supplemental data, analytical methods, and development of measures of uncertainty can all be evaluated and scored through the tier classification system in a systematic and relatively standardized manner. However, several of the criteria are more subjective, such as the degree of vessel and observer bias, spatial and temporal coverage, database and IT considerations, and statistical bias of estimators. Guidance on the more subjective criteria was provided by the NMFS National Bycatch Report Steering Committee to ensure consistency in scoring among regions,

[2] Vølstad, J. H., and M. Fogarty. 2006. Report on the National Observer Program Vessel Selection Bias Workshop, 17–19 May 2006, 532 p. Available from http://www.st.nmfs.noaa.gov/st4/nop/documents/Vessel_Selection_Bias_Report_final.pdf.

e.g., by providing common definitions of criteria such as partial and complete sampling frames, random, haphazard, stratified, and probability based sampling schemes.

Tier Classification

Five tiers (Tier 0–Tier 4) are identified for classification of U.S. commercial fisheries. To establish the range of scores for each tier, expected criterion scores for each tier were identified and then summed. These preliminary breaks were tested with sample data from well-studied fisheries. The scoring system performed successfully (e.g., sample fisheries anticipated to score in higher category tiers did so, while the sample fisheries with little or no bycatch data collection scored in the lower tiers). The system also successfully identified areas where improvements could increase the overall tier score. Table 5 below provides details on the tier categories.

Table 1.—Criteria and scores for adequacy of bycatch data.

Criteria	Score
Longevity of observer data	
No observer program has ever been implemented.	0
Observer program conducted prior to 1995.	1
Observer program conducted on one or more occasions during 1995–2000, but not annually.	2
Observer program conducted annually during 1995–2000 and not subsequently.	3
Observer program conducted on one or more occasions from 2001 to present, but not annually.	4
Observer program conducted annually from 2001 to present.	5
Sampling Frame	
No sampling frame.	0
Partial sampling frame.	2
Complete sampling frame.	3
Sampling Design	
Sampling of vessels, permits, licenses	
No observer program or sampling design does not support bycatch or total catch estimation.	0
Opportunistic or haphazard sampling, including voluntary observer programs, to support bycatch or total catch estimation.	1
Random sampling scheme or probability-based sampling with moderate observer coverage levels to support bycatch or total catch estimation.	2
Random sampling scheme or probability-based sampling with adequate observer coverage levels to support bycatch or total catch estimation.	3
Near-census of vessels with estimation required, or census of vessels with no estimation required.	4
Sampling of trips	
No observer program, or sampling design does not support bycatch or total catch estimation.	0
Opportunistic or haphazard sampling, including voluntary observer programs, to support bycatch or total catch estimation.	1
Random sampling scheme or probability-based sampling with pilot/baseline observer coverage levels to support bycatch or total catch estimation.	2
Random sampling scheme or probability-based sampling with adequate observer coverage levels to support bycatch or total catch estimation.	3
Near-census of trips with estimation required, or census of trips with no estimation required.	4
Sampling of hauls	
No observer program or sampling design does not support bycatch or total catch estimation.	0
Opportunistic or haphazard sampling, including voluntary observer programs, to support bycatch or total catch estitmation.	1
Random sampling scheme or probability-based sampling to support bycatch or total catch estimation.	2
Near-census of hauls with estimation required.	3
Census of hauls with no estimation required.	4
Design implementation	
Spatial coverage	
No observer program has ever been implemented.	0
Spatial coverage limited.	1
Spatial coverage synoptic.	2
Temporal coverage	
No observer program implemented.	0
Temporal coverage limited.	1
Temporal coverage synoptic.	2
Vessel selection bias	
Vessel selection bias high or unknown.	0
Vessel selection bias negligible or no bias exists.	2
Observer bias	
High or unknown.	0
Negligible or no bias exists.	2
Data quality control	
No observer program or no data quality control.	0
Limited or incomplete observer training, no debriefing or other quality control.	1
One-time observer training, no debriefing or other quality-control measures.	2
Periodic observer training, minimal quality-control measures.	3
One-time observer training, comprehensive quality-control measures.	4
Periodic observer training, comprehensive quality-control measures.	5
Industry bycatch data	
Industry bycatch data not available or industry bycatch data not used as a basis for bycatch estimates.	0
Industry bycatch data available prior to 2000 used as a basis for bycatch estimates.	1
Industry bycatch data available from 2000–present used as a basis for bycatch estimates.	2

Results and Discussion

The bycatch data for 152 U.S. commercial fisheries[3] are evaluated through the tier classification process. The bycatch data and estimate quality for each fishery are evaluated for three resource groups: fish, marine mammals, and other protected species (i.e., threatened or endangered species). In some regions, fisheries are grouped into higher-level fishery categories for estimation of protected species bycatch (by gear types, such as large-mesh gillnet). Thus, data and estimation methods for all three resource groups are not always available at the same level of fishery granularity. As a result, the total number of fisheries evaluated varies by category (fish: 142; marine mammal: 129; other protected species: 129, for a total of 400 unique tier scores).

To illustrate the tier scoring process, two cases studies are presented below, one for a low scoring fishery (Gulf of Mexico reef fish bottom longline) and one for a high scoring fishery (Bering Sea/Aleutian Islands pollock trawl). The examples provide information related to fish stocks only, but the application of the method is similar for the other species group categories (marine mammals and other protected species). Scores for individual criteria are presented in Table 6.

[3] Fisheries are defined within the *U.S. National Bycatch Report* (NMFS, 2011) as a combination of an area fished, target species, and gear type.

Gulf of Mexico Reef Fish Bottom Longline

The Gulf of Mexico reef fish bottom longline fishery is a Federal fishery that uses bottom longlines to target red grouper, *Epinephelus morio*; gag grouper, *Mycteroperca microlepis*; scamp, *Mycteroperca phenax*; and tilefish, Malacanthidae. Some bycatch data are available for this fishery: an observer program was in place prior to 1995, and logbooks are required under the fishery management plan. In addition, an internally reviewed estimation method was in place. However, given the lack of more recent observer data at the time of evaluation, insufficient supplemental data to expand existing estimates to the entire fishery, and unresolved assumptions, the overall score for this fishery was low (37 of a possible 73). This resulted in classification in Tier 2.

Bering Sea/Aleutian Islands Pollock Trawl

The Bering Sea/Aleutian pollock, Alaskan pollock, *Theragra chalcogramma,* also referred to as walleye, trawl fishery has a long-term observer program and self-reported program for collection of bycatch data, resulting in nearly the maximum scores for these elements. Supplemental data are available for use in extrapolation (including landing reports and production reports), and the analytical approach receives a high score: assumptions are tested and identified problems resolved, and the estimation methods are peer reviewed. This fishery is classified as Tier 4, with an overall score of 67 (of a possible 73). Improved measures of uncertainty and resolution of some statistical bias identified in the estimator would result in a maximum score for this fishery.

While providing the details of individual tier scores for each of the fisheries examined is beyond the scope of this paper (see NMFS (2011) for the full report), general trends and observations can be summarized. At a national level, the majority of fisheries (42%) are classified in Tier 3, while 15% fell into Tier 2, and 15% into Tier 1 (Fig. 1). Only 4% are classified in Tier 4. Bycatch data collection programs and/or estimation methods do not exist for 24% of the fisheries evaluated and these are therefore classified as Tier 0.

Comparison among NMFS regions is also possible (Fig. 3); regional differences may be due to many factors, including availability of resources for data collection and development of

Table 2.—Criteria and scores for availability of supplemental data.

Criteria	Score
Data available for use as extrapolation factors for unobserved components of the fishery	
Supplemental data not available as extrapolation factors.	0
Limited supplemental data available as extrapolation factors.	1
Extensive supplemental data available or data are not necessary as extrapolation factors.	2
Data available for stratification	
Supplemental data not available for stratification.	0
Limited supplemental data for stratification.	1
Extensive supplemental data available or data are not necessary for stratification.	2
Data available for imputation	
Supplemental data not available for imputation.	0
Limited supplemental data available for imputation.	1
Extensive supplemental data available or data are not necessary for imputation.	2
Data available for model covariates	
Supplemental data not available for model covariates.	0
Limited supplemental data available for model covariates.	1
Extensive supplemental data available or data are not necessary for model covariates.	2
Industry data verified	
Industry data not verified or no industry data available.	0
Some relevant industry data verified.	1
All relevant industry data verified.	2

Table 3.—Criteria and scores values for database/IT considerations.

Criteria	Score
Database / IT considerations	
No observer data and/or supplemental data available.	0
Analytical approach constrained due to database/IT considerations.	1
Analytical approach not constrained due to database/IT considerations.	3

Table 4.—Criteria and scores for analytical methodology.

Criteria	Score
Assumptions identified, tested, and deemed appropriate	
No bycatch estimation methodologies.	0
Assumptions not identified or tested.	1
Assumptions identified and tested, but no assumptions resolved.	3
Minor assumptions identified, tested, and determined to be appropriate or resolved.	5
Critical assumptions identified, tested, and determined to be appropriate or resolved.	8
All assumptions identified, tested, and determined to be appropriate or resolved.	10
Peer reviewed/published	
Observer program sampling design	
Not peer reviewed, or sampling design found to be seriously flawed during peer review.	0
Internally peer reviewed, or problems found during a peer review not fully addressed.	2
Externally peer reviewed (and passed).	4
Analytical approach	
Not peer reviewed, or analytical approach found to be seriously flawed during peer review.	0
Internally peer reviewed, or problems found during a peer review not fully addressed.	2
Externally peer reviewed (and passed).	4
Statistical bias of estimators	
No bycatch estimation methodologies or statistical bias unknown.	0
Estimators have high statistical bias.	2
Estimators have negligible statistical bias or not statistically biased, or census sampling.	4
Measures of uncertainty	
No bycatch estimation methodologies.	0
Measures of uncertainty not calculated.	1
Measures of uncertainty calculated, but not at all levels (vessel/permit/license, trip and haul).	2
Measures of uncertainty calculated at all levels (vessel/permit/license, trip and haul).	3

analytical methods, level of observer coverage required by regulation, and regional prioritization of fisheries for bycatch monitoring. The proportion of fisheries lacking bycatch estimates is greater for the Pacific Islands, Northwest, and Southeast Regions.

The Pacific Islands Region includes fisheries in many remote areas such as Guam, American Samoa, and the Northern Marianas Islands, where data collection programs are logistically challenging to implement. Similarly, in the Southeast, data collection programs are lacking for fisheries in the Caribbean.

On the West Coast, data collection programs for some comanaged fisheries in the Northwest (e.g., salmon and halibut), are not in place. Two NMFS regions, Alaska and the Northeast, have a large percentage of fisheries that scored relatively high. Not coincidentally, these two regions are also home to the largest observer programs, with 35,600 (Alaska) and 11,381 (Northeast) days-at-sea observed in 2005. However, it is important to note that, while the scale of observer programs provides some indication of the data collection efforts, high levels of coverage may not be necessary to obtain good estimates of bycatch (e.g., if the recommended coefficient of variation can be achieved with lower levels of coverage). This is often the case for commonly caught bycatch species. However, for rare-event species, higher levels of coverage are needed to achieve reliable estimates.

A comparison of bycatch data quality and reliability of bycatch estimation methods demonstrates that a large number of variations of point value combinations can occur as these criteria are applied to individual fisheries. However, a general increasing trend in the reliability of the bycatch estimates as quality of the bycatch data improves is observable (see NMFS, 2011:63). Also, some fisheries utilize relatively poor data in combination with high quality estimation methods while other fisheries have high quality data available that are not used to estimate bycatch.

Differences between the quality of bycatch data and the quality of the bycatch estimates are also apparent among bycatch categories (Fig. 4). The results of this comparison indicate that there is less data collection specifically targeted to bycatch of marine mammals and other protected species than to bycatch of fish (more than double the number of fisheries are classified in Tier 0 for marine mammals and other protected species than for fish). However, of the fisheries where data are available, the quality of the bycatch data and estimates is similar for fish species and for

Table 5.—Tier scores and descriptions.

Tier category	Range of scores	Description
Tier 4	66–73	Bycatch estimates were available and were based on the highest quality data and analytical methods.
Tier 3	49–65	Bycatch estimates were also generally available and higher quality data (e.g., data that are more reliable, accurate, and/or precise than those available in lower tiers) were utilized to compute these estimates.
Tier 2	32–48	Bycatch estimates were generally available. However, these estimates would have benefited from improvements in data quality and/or analytical methods (such as improved sampling designs, increased coverage levels, or peer review of methods). Where bycatch estimates were not available, methods are being developed.
Tier 1	1–31	Bycatch data were available but were generally unreliable (e.g., from unverified or potentially biased sources). In some cases, higher quality data were available but analytical methods had not been implemented.
Tier 0	0	Bycatch data collection programs or estimation methods did not exist, and, therefore, bycatch estimates were not available.

Table 6.—Point scores, by criterion, for the Gulf of Mexico reef fish bottom longline and Bering Sea/Aleutian Islands pollock trawl fisheries. Criteria descriptions have been condensed for ease of display.

Scoring Criteria	Maximum possible points	Gulf of Mexico reef fish bottom longline	Bering Sea/ Aleutian Islands pollock trawl
Adequacy of observer bycatch data			
Longevity of observer program	5	1	5
Sampling frame	3	2	3
Sampling design			
Vessels/permits/licenses	4	2	4
Trips	4	2	4
Hauls	4	2	3
Design implementation			
Spatial coverage	2	1	2
Temporal coverage	2	1	2
Vessel selections bias	2	2	2
Observer bias	2	2	2
Data quality control	5	3	5
Subtotal	33	18	32
Adequacy of industry bycatch data			
Subtotal	2	2	2
Supplemental data			
Extrapolation factors for unobserved components of the fishery	2	1	2
Stratification	2	1	2
Imputation	2	1	2
Model covariates	2	1	2
Industry data verification	2	1	2
Subtotal	10	5	10
Database / IT considerations			
Subtotal	3	1	3
Analytical approach			
Assumptions	10	3	8
Peer review/publication			
Observer program sampling design	4	2	4
Analytical approach	4	2	4
Statistical bias of estimators	4	2	3
Measures of uncertainty	3	2	1
Subtotal	25	11	20
Total	73	37	67
Tier	4	2	4

marine mammals and other protected resources (i.e., approximately 45% of fisheries in Tiers 3 and 4). This can be explained in part by the greater sampling intensity needed for estimating protected resources bycatch (as bycatch of protected species is a rare event), and because the United States takes a broad-based approach to sampling (e.g., sampling is generally designed to target species groups as opposed to individual species).

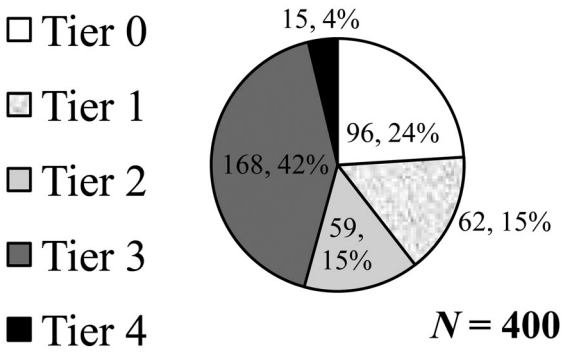

Figure 1.—Distribution of overall fishery tier scores (number, percent) for the year 2005, summed across fisheries, NMFS regions, and bycatch categories.

Conclusions

Managers and scientists are faced with difficult decisions in allocating resources for monitoring fisheries and developing methods for estimating bycatch. Lack of objective criteria make this particularly challenging. In developing the tier classification system, NMFS scientists and managers from across the nation crafted a tool that that would aid in the decision-making process and that could also be used to track improvements in bycatch estimates over time.

The approach described in this paper is already proving to be useful to the agency. For example, in the Northeast and Southwest Regions, bycatch data were available at the time the *U.S. National Bycatch Report* was developed, but they were not being used to develop bycatch estimates for some fisheries and species. Following their work on the National Bycatch Report, the Northeast and Southwest Regions implemented recommendations to develop seabird

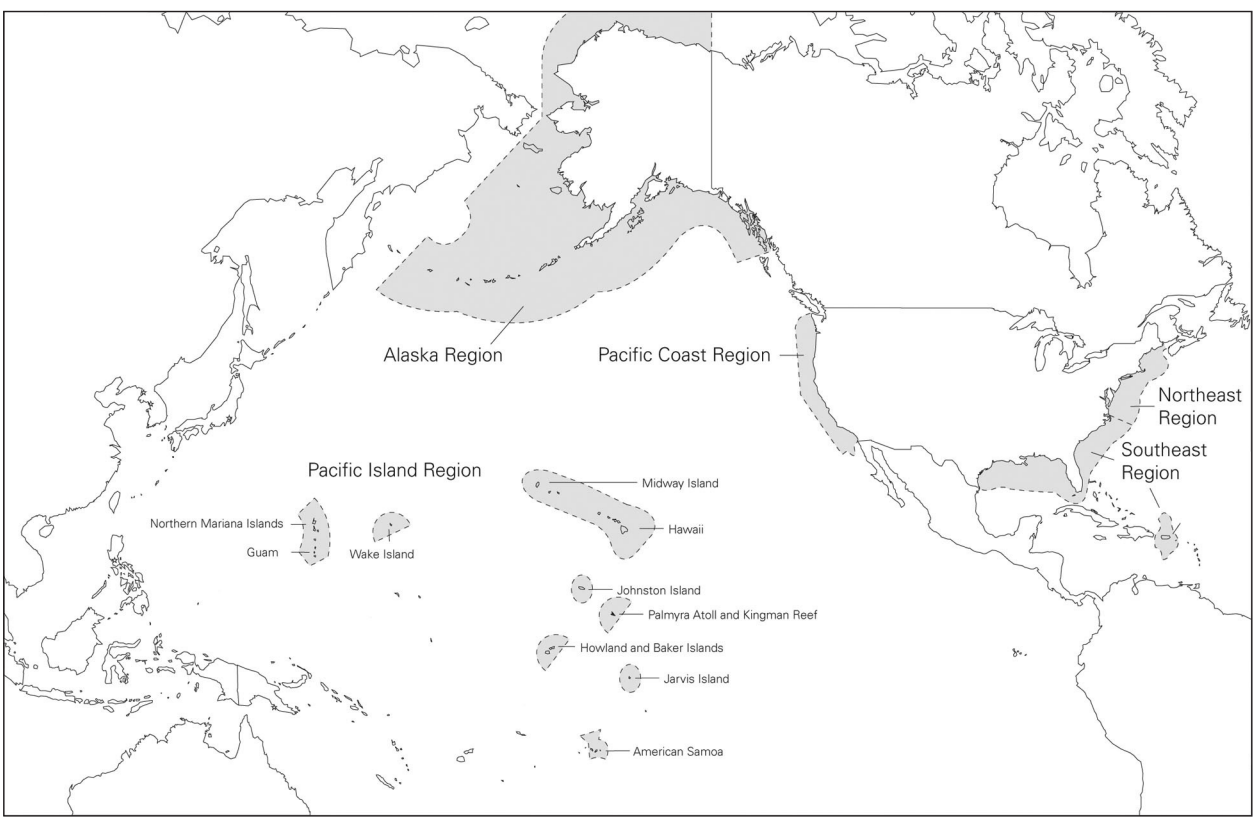

Figure 2.—NMFS fishery management regions.

bycatch estimates (Northeast) and fish bycatch estimates (Southwest). We expect to see further improvements relative to the number of fisheries for which reliable bycatch information is available, and improvements relative to overall bycatch rates and levels.

We recognize that this is the first attempt to develop and implement an approach of this type, and we expect that refinement will be made in the future. The basic data that are used to develop the tier scores reported in the first edition of the *U.S. National Bycatch Report* (NMFS, 2011) are provided within the report itself. Thus, any changes that are made to the system in the future can be applied retrospectively. This will enable tracking of performance over time to maintain its initial reference point with the baseline established in the first *U.S. National Bycatch Report*.

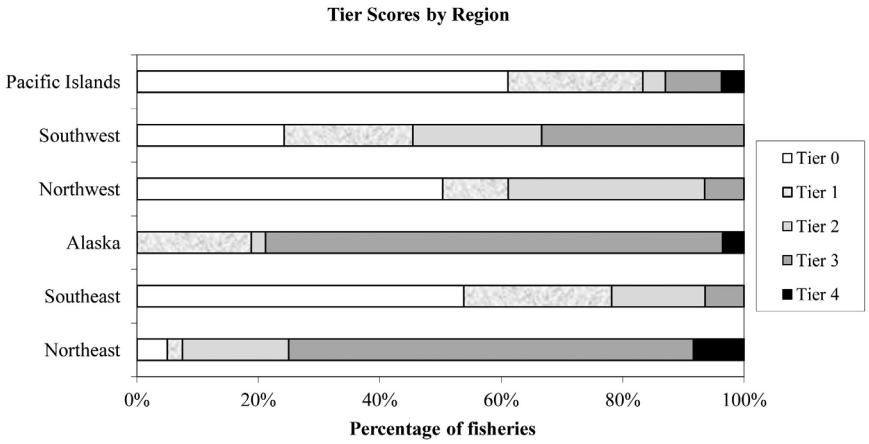

Figure 3.—Comparison of 2005 fishery tier score results among NMFS regions (for U.S. commercial fisheries only).

Acknowledgments

The authors of this paper would like to acknowledge the many NMFS staff members in the headquarters and regional offices and in the fisheries science centers who contributed to the *U.S. National Bycatch Report*. A collaborative effort, the report is the product of extensive data, information, comments, suggestions, and research

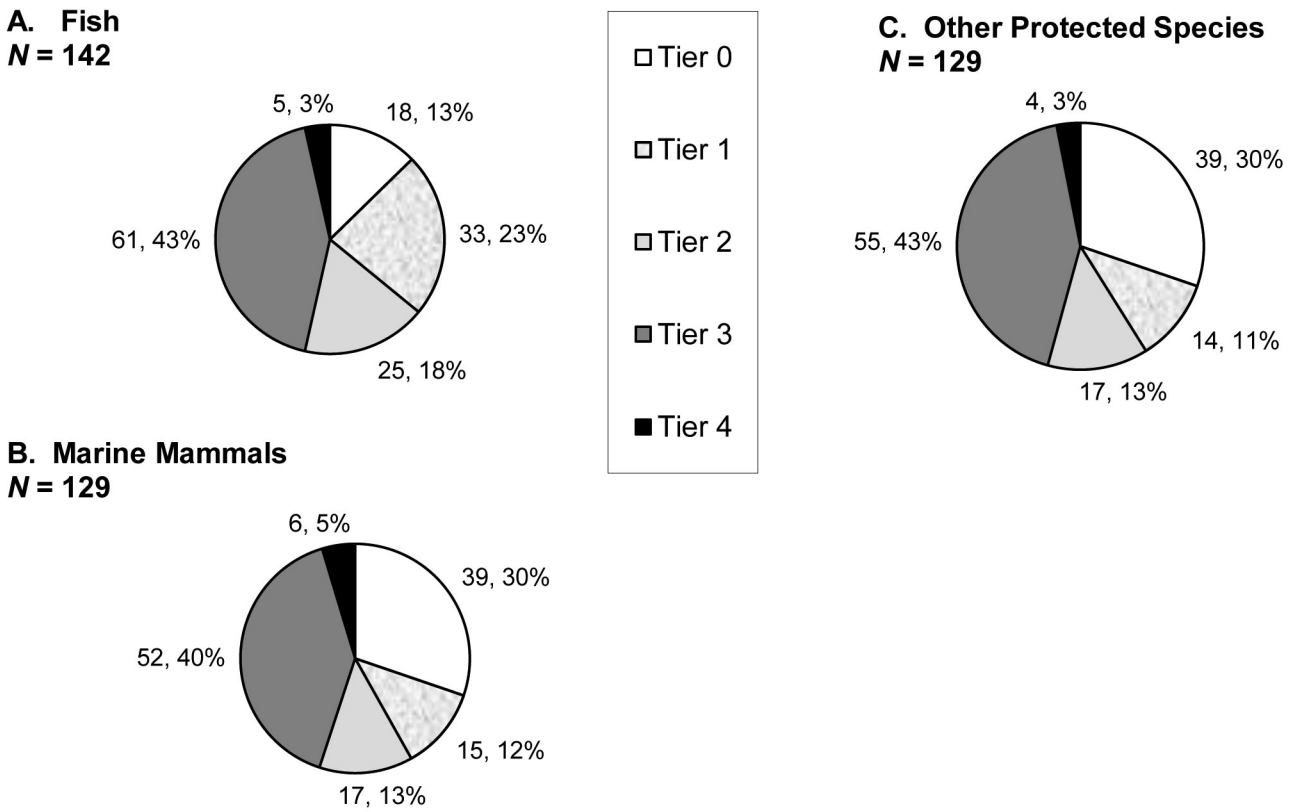

Figure 4.—Distribution of fishery tier scores (number, percent) across U.S. commercial fisheries in all NMFS regions for 2005 bycatch data and estimation of A) fish, B) marine mammals, and C) other protected species.

provided by colleagues throughout NMFS. We thank them for their efforts in ensuring the accuracy of the information included in the report, as well as for providing insight into national and regional bycatch concerns. Without their support, the report, and this paper, would not have been possible. We also thank the hundreds of fisheries observers who each year spend countless hours collecting the data relied on to monitor the nation's bycatch.

Literature Cited

Harrington, J. M., R. A. Ransom, and A. A. Rosenberg. 2005. Wasted resources: bycatch and discards in U.S. fisheries. U.S. Atlas of fisheries bycatch, prepared by MRAG Americas, St. Petersburg, Fla., 286 p.

Kelleher, K. 2004. Discards in the world's marine fisheries: an update. FAO Tech. Pap. 470, 134 p.

Moore, J. E., B. P. Wallace, R. L. Lewison, R. Zydelis, T. M. Cox, and L. B. Crowder. 2009. A review of marine mammal, sea turtle, and seabird bycatch in USA fisheries and the role of policy in shaping management. Mar. Pol. 33:435-451.

NMFS. 2001. Marine fisheries stock assessment improvement plan. Report of the national marine fisheries service national Task Force for improving fish stock assessments. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-56, 69 p.

_____ . 2004. Evaluating bycatch: a national approach to standardized bycatch monitoring programs. U. S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-66, 108 p.

_____ . 2011. U.S. National Bycatch Report. [W. A. Karp, L. L. Desfosse, and S. G. Brooke, Editors]. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-117A, 508 p.