

# Estimating Overall Fish Bycatch in U.S. Commercial Fisheries

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## Introduction

Bycatch, or the unintended capture of fish, marine mammals, sea turtles, and seabirds by fishing gear, occurs when fishermen are required to discard animals due to regulatory constraints, or when they choose to discard animals for economic (market condition) reasons. It is impossible to design fishing gear that captures only animals that can be retained legally or will obtain the best market price. Thus, bycatch and discard take place in almost all fisheries.

Biological impacts of bycatch have been demonstrated at the species, population, and ecosystem levels (Hall et al., 2000; Kelleher, 2004; Lewison et al., 2004; Read et al., 2006). Economic

impacts may also be substantial when current or potential future exploitable biomass is not available for harvest (Pascoe, 1997; Larson et al., 1998; Kelleher, 2004). The bycatch of endangered, threatened, or overfished species is of particular concern.

NOAA's National Marine Fisheries Service (NMFS) is required under the Magnuson-Stevens Fishery Conservation and Management Act, Marine Mammal Protection Act, and Endangered Species Act to inventory and reduce bycatch and bycatch mortality (16 USC 1851(a)(9), 16 USC 1362(9), and 16 USC 1536 (a)(2)). To carry out this mission, reliable, quantitative information on bycatch is required. The recently published *U.S. National Bycatch Report* (NMFS, 2011) documents bycatch estimates and bycatch estimation methods for commercial fisheries for which this information was available in 2005.<sup>1</sup>

<sup>1</sup>The year 2005 was selected during the report's development in 2006 as the most recent year for which complete information was available. The NMFS intends to publish updated information in future versions of this report.

The report provides 81 fishery-level bycatch estimates, as well as more than 400 stock-, species-, or group-level estimates for fish, marine mammals, seabirds, and sea turtles. Using the information contained in the report, a national bycatch ratio was calculated as the basis for computing an overall national fish<sup>2</sup> bycatch estimate. A bycatch ratio is calculated by dividing bycatch by total catch (bycatch plus landings). Because this approach is only applicable when catch and bycatch data are both reported as weights, data reported as numbers of individuals cannot be taken into account unless reliable length-weight conversion factors are available. A national bycatch estimate was calculated only for fish species and does not include marine mammals, seabirds, or sea turtles.

The *U.S. National Bycatch Report* provides overall regional and national bycatch estimates, and bycatch ratios for specific gear types. These results will provide reference points for future monitoring and mitigation efforts. National bycatch ratios and national bycatch estimates for U.S. commercial fisheries have been calculated previously by the Food and Agriculture Organization of the United Nations (FAO) (Kelleher, 2004) and Harrington et al. (2005) based on published bycatch data. The *U.S. National Bycatch Report* provides a more recent estimate based on detailed NMFS bycatch and landings data, as well as some published estimates. Here we report on the methods used to develop the national bycatch estimate and national bycatch ratio, present national and regional results, and discuss how the resulting statistics compare with previously published estimates.

<sup>2</sup>"Fish" are defined in the context of the report to include both fish and invertebrate species.

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**ABSTRACT**—Bycatch, or the unintended capture of fish, marine mammals, sea turtles, and seabirds by fishing gear, occurs to some degree in most fisheries. The recently released *National Marine Fisheries Service's (NMFS) U.S. National Bycatch Report* provides information on bycatch in U.S. commercial fisheries by fishery and species. The report also provides national statistics in the form of national bycatch ratio and a national bycatch estimate. We describe the methods used to develop these statistics and compare them to similar studies. We conclude that the national bycatch ratio and national bycatch estimates developed by NMFS represent the best available information on bycatch in

U.S. fisheries. However, given changes in bycatch management over time, as well as inter-annual variability in bycatch levels and a high percentage of fisheries for which data on bycatch are not currently available, we recommend that NMFS continue to support bycatch data collection and reporting efforts to improve the quality and quantity of bycatch data and estimates available to fisheries managers and scientists over time. This will enable NMFS to meet its requirements for bycatch reporting under the Magnuson-Stevens Act (MSA), as well as requirements for bycatch minimization under the MSA, Marine Mammal Protection Act, and Endangered Species Act.

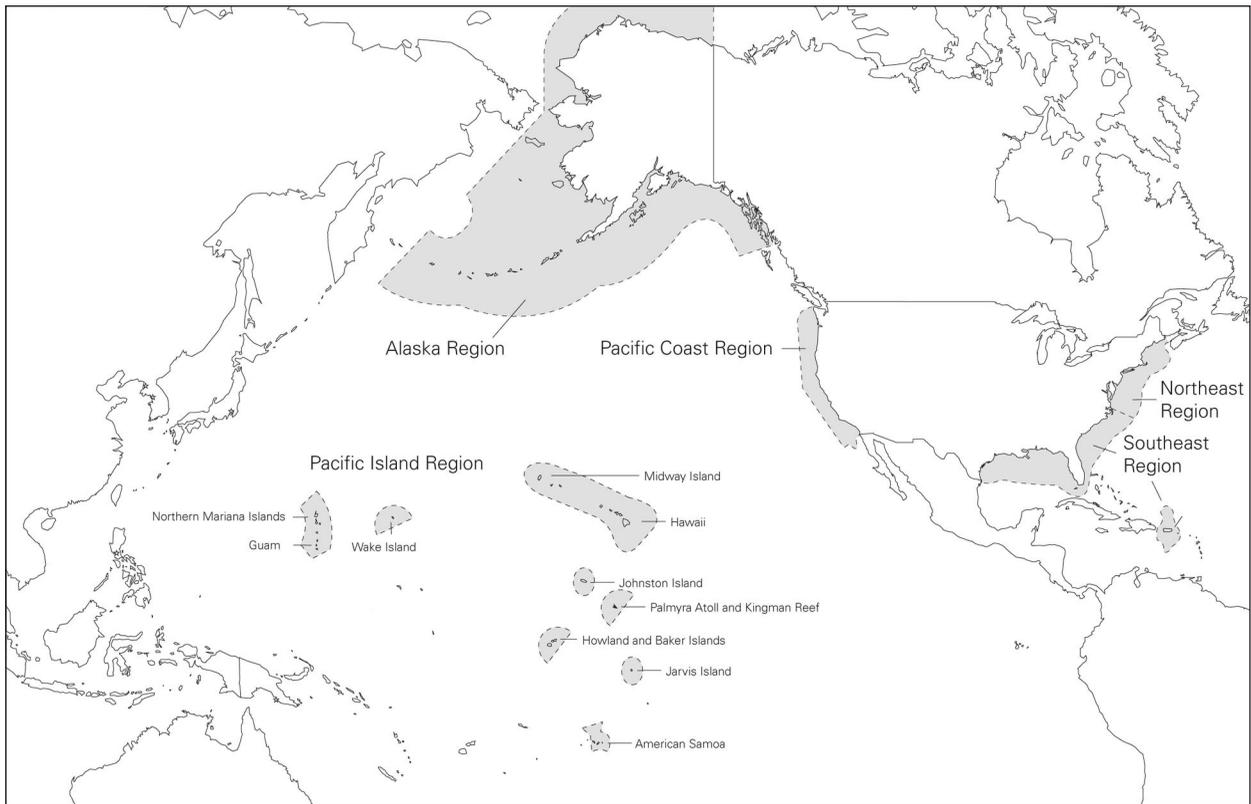


Figure 1.—NMFS Management Regions.

## Data

Bycatch data (where bycatch is defined as animals returned to the sea alive or dead) were compiled by NMFS region (Fig. 1)<sup>3</sup>, fishery, and species. Data were primarily from fisheries that occurred in 2005, although calculation of estimates for rare-event species bycatch required data from a range of years in some cases. The bycatch estimates included in this report include both previously published and newly calculated estimates. Data sources available for estimation varied by fishery but included observer and self-reported information (e.g., logbook, production, and dealer reports). Landings and bycatch data by fishery and species were used to calculate fishery-specific bycatch estimates. Total

<sup>3</sup>There are six NMFS regions: Northeast, Southeast, Alaska, Northwest, Southwest, and Pacific Islands.

## Methods

bycatch and landings for a given fishery were obtained from individual NMFS regional offices. Detailed information on estimation methods and regional bycatch estimates by fishery and species can be found in the *U.S. National Bycatch Report* (NMFS, 2011).

Only Federal commercial fisheries and fisheries with Federal data collection programs were considered in this first version of the *U.S. National Bycatch Report*, as data from these fisheries were most easily accessible. These fisheries numbered 152, and fishery-level bycatch estimates for fish were reported for 70 of them.<sup>4, 5</sup> Individual

<sup>4</sup>Only fisheries with bycatch estimates for fish are included in this total: while a total of 81 fishery-level estimates were available, some of these estimates were for fisheries with protected species bycatch only. Protected species bycatch estimates are always reported as numbers and were not included in these regional and national ratio estimates.

<sup>5</sup>A complete list of fisheries identified by the *U.S. National Bycatch Report* is available in NMFS (2011).

fisheries were defined by combinations of gear, target species, and area. For nine fisheries (two fisheries in the Northwest Region, seven in the Southeast Region), some or all components of the fish bycatch were reported by numbers rather than weight.<sup>6</sup> Since conversion factors were not available in these instances, these fisheries were excluded from the overall analysis. Thus data for 61 fisheries were used to estimate the national bycatch ratio.

## National Bycatch Ratio

Estimates of total bycatch and total landings for each of these 61 fisheries were summed by region and then summed across regions to provide total summed bycatch and total summed

<sup>6</sup>The reason for reporting in numbers of individuals varies: in the Northwest Region, estimates are based on encounter rates and are managed in numbers of fish. In the Southeast Region, fishermen complete logbooks, where they report catch as numbers of individuals.

landings estimates for the 61 fisheries (Table 1). The national bycatch ratio,  $r$ , was calculated from these sums as  $b/(b+1)$  where  $b$  = total summed bycatch and  $1$  = total summed landings. This approach is consistent with recently published reports that provide comparable information (e.g., Kelleher, 2004, and Harrington et al., 2005).

### National Bycatch Estimate

Since bycatch data were not available for all U.S. commercial fisheries, the national bycatch ratio described above was used to estimate the bycatch of fish for fisheries that lacked specific bycatch estimates. These regional estimates were then summed to provide a national bycatch estimate. This approach makes the assumption that bycatch ratios for fisheries where bycatch data are lacking are comparable to those for which bycatch data are available, and the assumption is open to legitimate criticism. Other methods for expansion were considered, including applying proportional or gear-based ratios, however, these were open to other types of bias. The method used by the authors of the *U.S. National Bycatch Report* is a standard method to expand bycatch estimation to all U.S. commercial fisheries and was employed by the authors of the comparative reports cited above. Thus, for each region,

$$b_u = (r \times I_u) / (1 - r),$$

where  $b_u$  = estimated total bycatch for the subset of regional fisheries for which bycatch was unknown (i.e., those fisheries not considered in the report);

$r$  = the national bycatch ratio calculated for all fisheries where data were available (i.e., those fisheries considered in the report); and

$I_u$  = landings for the subset of regional fisheries for which bycatch was unknown (obtained by subtracting landings for fisheries with bycatch estimates from total landings<sup>7</sup>).

Even though variance estimates were available for some individual fishery bycatch estimates, they were not available in many instances. Where variance estimates were available, they were developed with dissimilar methods. Thus, it was not possible to compute measures of uncertainty for overall regional bycatch estimates, or for the national estimate. Methods for calculating uncertainty are being evaluated and developed to improve bycatch data presented in future versions of the report.

### Results

Through the process described above, we estimated that 1.93 billion pounds of fish were discarded in 2005 for 9.61 billion pounds of fish landed during the same period (Table 2). Bycatch data for 61 fisheries were used to calculate the regional bycatch ratios, which provided the basis for this national estimate. Fisheries with bycatch estimates accounted for 63% of the total landings for all fisheries. Regionally, sampling for bycatch

<sup>7</sup>Total landings for all fisheries for each region were obtained from the NMFS commercial landings database (<http://www.st.nmfs.noaa.gov/st1/commercial/index.html>).

**Table 1.—Number of fisheries considered in the U.S. National Bycatch Report by NMFS region, and associated regional landings and fish bycatch for 2005. Weights have been rounded to the nearest thousand pounds.**

NMFS region	No. fisheries with bycatch estimates by weight	Fish bycatch (lb)	Fish landings (lb)
Northeast	25	165,888,000	1,006,370,000
Southeast	2	682,691,000	219,086,000
Alaska	27	338,573,000	4,487,167,000
Northwest	5	25,564,000	332,396,000
Southwest	0		
Pacific Islands	2	8,556,000	23,000,000
National total		1,221,272,000	6,068,019,000

ranged from 79% of the landings in the Alaska Region to 17% in the Southeast Region and 0% in the Southwest Region. A national bycatch ratio of 0.17 (0.167543 actual) was derived.

Estimated bycatch ratios varied among regions and ranged from 0.76 in the Southeast Region to 0.07 in the Alaska and Northwest Regions (Fig. 2). It was not possible to calculate a bycatch ratio for the Southwest Region, because no bycatch estimates were available for 2005 at the time the report was drafted.

In some cases, a single fishery played a significant role in influencing regional bycatch ratios. Examples include the Alaska pollock, *Theragra chalcogramma*, fishery, which is a relatively clean, high-volume fishery (3 billion pounds of landings and a bycatch ratio of 0.01), and the Southeast shrimp trawl fishery, which has high bycatch and landings levels (894 million pounds of landings and a bycatch ratio of 0.76 (NMFS, 2011)).

The report also examined bycatch ratios by gear type (Fig. 3). Mean ratios were similar for trawl, gillnet, and longline fisheries (0.24, 0.23, and 0.23, respectively), which were twice as high

**Table 2.—Fish bycatch and landings for 2005 by NMFS region for fisheries included in the U.S. National Bycatch Report, and estimated regional bycatch ratios.**

Region	2005 Landings (lb)			2005 Bycatch (lb)				
	Considered in report	Not considered in report	Total	Total landings sampled (%)	Considered in report	Regional bycatch ratios <sup>1</sup>	Not considered in report	Total
Northeast	1,006,370,000	385,816,000	1,392,186,000	72	165,888,000	0.14	77,651,000	254,539,000
Southeast	219,086,000	1,093,033,000	1,312,119,000	17	682,691,000	0.76	219,987,000	902,678,000
Alaska	4,487,167,000	1,164,140,000	5,651,307,000	79	338,573,000	0.07	234,299,000	572,872,000
Northwest	332,396,000	523,464,000	855,860,000	39	25,564,000	0.07	105,354,000	130,918,000
Southwest	—	367,830,000	367,830,000	0			74,031,000	74,031,000
Pacific Islands	23,000,000	9,244,000	32,244,000	71	8,556,000	0.27	1,860,000	10,416,000
National total	6,068,019,000	3,543,527,000	9,611,546,000	63	1,221,272,000	0.17	713,182,000	1,945,454,000

<sup>1</sup>Regional bycatch ratios include only fisheries considered in the *U.S. National Bycatch Report*.

as dredge and “other” fisheries (0.11 and 0.08, respectively). Variability differed within gear types and was greatest for “trawl” fisheries; this is due, in part, to the aggregation of bottom and pelagic trawl fisheries into a single category. Bycatch in pelagic trawl fisheries is generally lower than in bottom trawl fisheries (Alverson et al., 1994; Harrington et al., 2005). It is recognized that bycatch estimates from pelagic and bottom trawls may be different, and separate gear-based ratios will be calculated in future versions of the report.

## Discussion

The overall fish bycatch ratio for U.S. commercial fisheries presented here (0.17) is somewhat lower than other recently reported estimates for U.S. fisheries (Kelleher, 2004, and Harrington et al., 2005; both with bycatch ratios of 0.22). Correspondingly, the overall total bycatch estimate presented in this report (1.93 billion pounds) is lower than reported by FAO (Kelleher, 2004: 2.045 billion pounds) and Harrington et al. (2005: 2.333 billion pounds). It is

important to note that each report was compiled from data covering different base years (Kelleher in 2002; Harrington et al. in 2002–03) and different fisheries. Comparisons should, therefore, be made with caution.

Authors of those earlier reports obtained bycatch estimates and associated landings data from published and gray literature. The estimates contained in the *U.S. National Bycatch Report* are based on raw data as well as data obtained from a range of published and unpublished reports. In addition, Kelleher (2004) reported that their database may be biased in favor of fisheries with high discard rates. This type of positive bias is also likely for the Harrington et al. (2005) report, given that resources available to the public tend to focus on fisheries with high bycatch levels. Furthermore, considerable interannual variability in catch and bycatch rates can be expected, and this further constrains comparisons of results obtained from different datasets.

Since the NMFS *U.S. National Bycatch Report* is more comprehensive and includes fisheries with and without bycatch concerns, the bycatch ratio estimate for 2005 is more representative than those previously published. Nevertheless, it is important to stress that this new report only includes data from 61 of 152 Federal fisheries evaluated, because bycatch estimates were not available (or were not available in the necessary units) for the remaining 91. A primary concern with the use of a bycatch ratio is the assumption that existing information is representative of those fisheries or sectors where data are not available. In addition, because bycatch of marine mammals, sea turtles, and seabirds is reported in number of individuals, rather than weights, the total amount of bycatch is under-represented by this ratio.

The *U.S. National Bycatch Report* provides recommendations for improvements in data collection and data analysis programs to address this concern. In particular, implementation of bycatch estimation methods that also provide variance estimates is strongly encouraged to estimate uncertainty. The

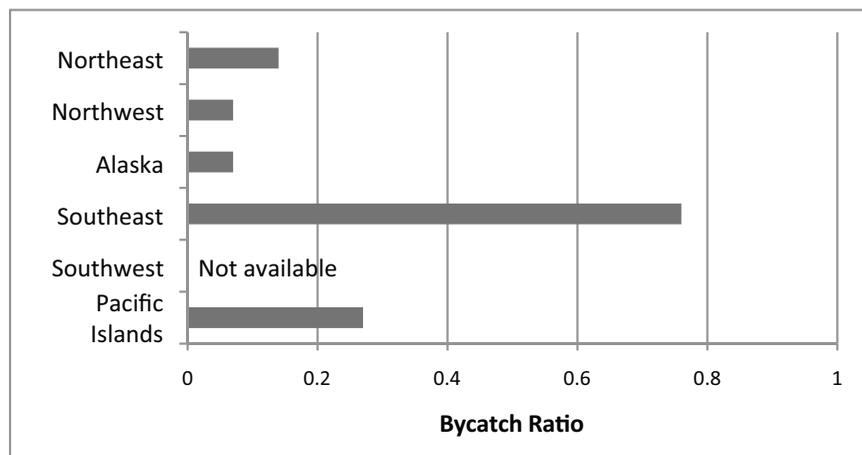


Figure 2.—Regional bycatch ratios, where the bycatch ratio is defined by the formula bycatch/ (bycatch+landings).

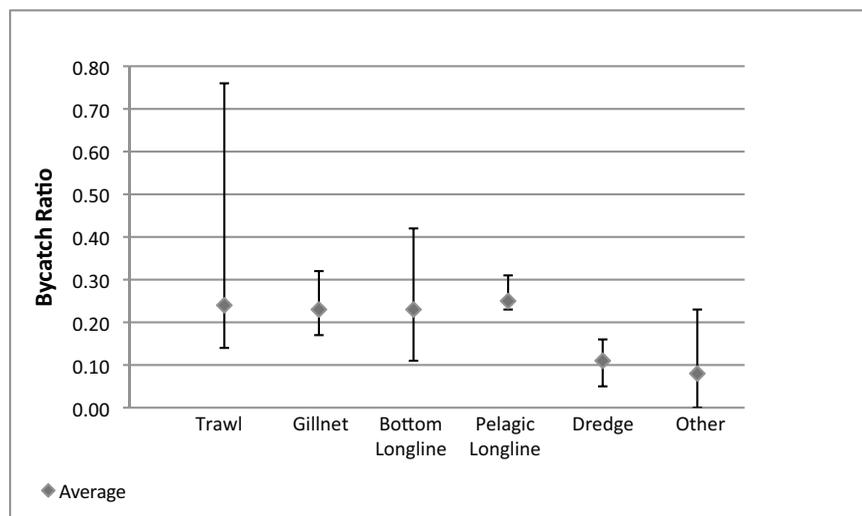


Figure 3.—Bycatch ratios, by generalized gear types. Both the average ratio and the range of ratios are shown. Other gear = jig, handline, pot, and purse seine.

development of length-weight conversion methods for the nine fisheries where fish bycatch is currently estimated in numbers of individuals will improve the quantity of information contained in the report. For example, in the Southeast Region bycatch data for many fisheries are available, but was collected through logbook programs in numbers of individuals; converting these estimates to weights will increase the percentage of fisheries with bycatch estimates in this region (NMFS, 2011).

Newly developed bycatch estimates will also expand the information contained in the *U.S. National Bycatch Report*. In particular, estimates for the California set gillnet fishery and the California drift gillnet fishery in the Southwest Region provide important information on bycatch in that region (Larese and Coan, 2008; Larese, 2009). Seabird bycatch estimates were developed for Northeast gillnet fisheries (Warden, 2010), and updated sea turtle bycatch estimates are available for the Southeast shrimp trawl fishery (SEFSC<sup>8</sup>). Improvements in data qual-

ity and inclusion of data from additional fisheries in future versions of the *U.S. National Bycatch Report* will result in overall improvements in the quality of the regional and national estimates and in a report that better represents regional and national bycatch levels and trends.

Since reporting on bycatch and tracking change in bycatch statistics is of considerable importance to NMFS, the *U.S. National Bycatch Report* will be updated on a regular basis, and data from new fisheries will be included as they become available. The information provided in the first edition of the *U.S. National Bycatch Report* (NMFS, 2011), as well as that from planned periodic updates, will allow managers to monitor bycatch levels of fisheries and species over time. This information will assist scientists and managers in evaluating the impact of bycatch reduction measures, and in identifying fisheries where additional such measures should be considered.

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