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Sea turtle bycatch to fish catch ratios for differentiating Hawaii longline-caught seafood products

Paul K. Bartram, J. John Kaneko *, Katrina Kucey-Nakamura

PacMar Inc., Suite 409, 3615 Harding Avenue, Honolulu, Hawaii 96816, USA

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ABSTRACT

Sea turtles can be incidentally caught in pelagic longline fishing gear targeting tuna and swordfish. Bycatch to fish catch (B/C) ratios can differentiate seafood based on sea turtle impacts. This study demonstrates the use of B/C ratios indexed to the weight of fish catch: (1) to report on the significant progress in reducing sea turtle bycatch in Hawaii's swordfish longline sector and (2) to compare Hawaii and other Pacific longline fisheries by number of sea turtle interactions per weight of catch. Hawaii's longline tuna fishery sets the benchmark of 1 sea turtle interaction per 190,000 kg of tuna caught.

1. Introduction

1.1. Purpose of study

Incidental catches of sea turtles are rare in Hawaii and other central and western Pacific pelagic longline fisheries [1]. Yet, protection of these and other charismatic marine species, such as seabirds and marine mammals, has become a very important, if not dominant factor in fisheries management [2]. Sea turtles are protected under the US Endangered Species Act. Unintentional fishery interactions with these threatened or endangered species are one example of ecosystem impacts that affect the public perception of the sustainability of seafood produced by longline fisheries.

Consumers are often unaware of the environmental consequences they implicitly endorse when buying seafood from different sources. As awareness of environmental issues associated with fishing and fishery products grows, consumer preferences and market demand for particular species and sources of seafood can be influenced [3]. As a matter of corporate responsibility marketers need to adopt sustainable seafood purchasing standards that specify objective and measurable criteria for determining the sustainability of different sources of seafood. To more effectively support responsible fisheries, practical measures to easily differentiate seafood harvested sustainably using low-impact methods from seafood of less sustainable origins are needed.

Existing scientific measures of fishery impacts on protected species are based on the rate of interactions per measure of fishing effort. But this is not intuitively translated to impacts associated with a weight of seafood produced. Different measures and new communication tools for readily conveying such information are needed. The practical question for the tuna and swordfish market is which product source carries with it the least amount of "environmental baggage" by weight of the seafood.

The purpose of this study is to demonstrate how Bycatch to Catch (B/C) ratios can answer this question. B/C ratios were used to establish a benchmark, track the progress of Hawaii's swordfish longline sector in reducing sea turtle bycatch and to compare fishery products from Hawaii and other Pacific longline fisheries by the number of sea turtle interactions per weight of seafood.

1.2. Why sea turtles are captured incidentally in longline fisheries

Incidental catch of sea turtles may occur when feeding animals opportunistically encounter baited longline hooks or when they are accidentally entangled with longline gear. These interactions take place during the pelagic periods of sea turtles' lives while migrating through the open ocean where their density is low, and to and from inshore feeding or breeding/nesting habitats where they are more likely to be aggregated at greater density.

Sea turtles rely on their visual senses in the search for food and need to surface at regular intervals to breathe. Some species also exhibit a preference for distinct ocean thermal regimes. These basic attributes have implications for the likelihood of potential interactions with pelagic longline fishing gear and the outcomes of those interactions [4].

The general design of pelagic longline gear is relatively simple but it is not a single or uniform method of fishing. There are considerable differences between and within fishing fleets. A

* Corresponding author. Tel.: +1 808 735 2602; fax: +1 808 734 2315.
E-mail address: pacmar@pacmarinc.com (J. John Kaneko).

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mainline is deployed horizontally for up to 40 miles across the ocean. It is suspended in the water column between multiple float lines and floats. Branching lines ending in baited hooks descend vertically from the mainline at intervals between floats that cause each array of hooks to deploy through a range of ocean depths. The depth of the hooks is determined in large part by the length and sinking rate of the mainline between floats, and the length of the float lines and branchlines. Longline fishing is done in "sets" which begin with deploying the gear and end when all the gear has been retrieved.

The rate of sea turtle bycatch depends on how longline gear is configured, where and when gear is set in relation to the habitat, distribution and abundance of turtles, and behavior of turtle species. Sea turtles are air breathers and inhabit the upper layers of the ocean, especially the upper 50 m ("turtle layer"). When longline gear is set relatively shallow in the water column to target swordfish, most hooks are deployed within the "turtle layer", where there is a higher likelihood of interactions with sea turtles. When gear is set deeper to target bigeye tuna, the majority of hooks are deployed below the "turtle layer", so that there are fewer interactions with sea turtles [4].

1.3. Sea turtle bycatch

Incidental catch of sea turtles in US fisheries is considered a type of "bycatch". The US Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) guides Hawaii longline fisheries management. Under the MSFCMA definition, bycatch of sea turtles includes all animals released after interaction with fishing gear regardless of their fate.

Other definitions of marine bycatch are based on mortality and waste. According to Hall [2], bycatch is limited to marine species released after incidental capture either dead or with a poor chance of survival. The present study utilizes Hawaii longline sea turtle bycatch data collected by the National Oceanic and Atmospheric Administration (NOAA) Fisheries Service following the MSFCMA definition. Sea turtle bycatch is measured in "takes" from NOAA Fisheries' shipboard observer records that are defined as all interactions with longline gear, regardless of whether animals are dead, injured, or alive and unharmed when released [5].

1.4. Hawaii longline fisheries

A tuna longline fishery was first established in Hawaii in 1917. This fleet remained relatively small until the late 1980s, when new US boats entered the fishery from the US Pacific and Atlantic coasts and the Gulf of Mexico. Contributing to this fleet expansion was the discovery of commercial concentrations of swordfish north of Hawaii. The new fishery diversified the Hawaii longline fleet into a deep-set sector targeting bigeye tuna and a shallow-set sector targeting swordfish [6].

Concerns about unrestrained fleet expansion and possibility of future over-capacity caused the Western Pacific Fishery Management Council to recommend a limited entry system for NOAA Fisheries approval and implementation. A moratorium on new vessel entry to Hawaii longline fisheries was established in 1991 and this evolved into the present limited access permit system [7]. The number of permitted vessels was capped at a maximum of 164 vessels, but the Hawaii longline fleet has numbered 141 vessels or less since the limit was established [8].

Both sectors of Hawaii longline fishery operate under the US Endangered Species Act (ESA), as well as the MSFCMA. The ESA requires NOAA Fisheries to set maximum limits for annual Hawaii longline fishery interactions with sea turtles because of their protected status. Since 1994, Hawaii longline vessels have been required to carry shipboard observers when requested by NOAA Fisheries to monitor interactions with sea turtles and other protected species. During the first 6 years of the Hawaii longline observer program (1994–1999), observers accompanied 3–5% of fishing trips by the Hawaii fleet. The sea turtle interactions actually observed during this period were rare, but statistical expansion of the limited data to the entire fishery suggested that several hundred turtles might be impacted annually. As a result, a NOAA Fisheries' Biological Opinion issued in 2001 temporarily closed the swordfish sector of the Hawaii longline fishery and prohibited tuna longline trips south of 15 N. latitude to the equator during the months of April and May [9].

1.5. Management regime change in the Hawaii longline fisheries

As a result of court orders and NOAA Fisheries' Biological Opinions and regulations, the Hawaii swordfish longline fishery was re-opened in 2004 after significant management measures were implemented to reduce sea turtle interactions [10]. Under the new management regime, swordfish directed effort has been capped at 2120 shallow-set longline sets per year. Vessel operators must declare to NOAA in advance of each trip whether swordfish (shallow sets) or tuna (deep sets) will be made. They must also submit shallow-set certificates for each shallow set made during a swordfish trip to NOAA within 72 h of each landing. Vessels making shallow sets north of the equator are required to use only circle hooks sized 18/0 or larger with a 10° offset and only mackerel-type bait (no squid) that have been shown to reduce the rate and severity of sea turtle hooking events. All Hawaii longline vessels (tuna and swordfish) must carry and use NOAA approved de-hooking devices. The level of observer coverage was increased to a minimum of 20% of Hawaii tuna longline trips (since mid-2001) and 100% of Hawaii swordfish longline trips (since mid-2004) [11]. Following the increased shipboard observer coverage, the level of sea turtle interactions in both sectors was more accurately quantified than previously. The Hawaii swordfish fishery operates with a real-time annual hard cap of 16 leatherback and 17 loggerhead interactions. If either species cap is reached, regardless of the severity of the interaction (including the live release of unharmed animals) the fishery is closed immediately for the remainder of the year.

1.6. Reduction of sea turtle bycatch in Hawaii's swordfish longline fishery

The Hawaii longline swordfish fishing industry, working with fisheries scientists and managers, has made significant progress in reducing incidental interactions with sea turtles. Management measures that were conditions of re-opening the swordfish sector in mid-2004 have resulted in a substantial and well-documented 89% reduction in bycatch per unit effort (BPUE) from 0.174 (1994–1999) down to 0.019 (2004–2006) incidental captures of all sea turtle species per 1000 hooks set in the Hawaii swordfish sector [12].

2. Methodology

Bycatch to catch (B/C) ratios are proposed as an index for representing and comparing sea turtle impacts in relation to the weight of target fish catches. Dr. Martin Hall of the Inter-American Tropical Tuna Commission first used B/C ratios to compare the bycatch impacts of different purse seine fishing methods in eastern Pacific tuna fisheries [2].

B/C ratios are derived by dividing a fishery's CPUE (fish catch weight per unit of fishing effort) by its BPUE (bycatch per unit of fishing effort). CPUE is usually estimated from logbook reports of fish catch and effort, whereas BPUE (number of sea turtle takes per unit of fishing effort) can only be reliably estimated from shipboard observer monitoring (Table 1). Detailed notes on the source data, assumptions and calculations for each of the fisheries compared are given in Table 1.

Sea turtle bycatch, estimated as number of fishery interactions, or "takes", range for non-lethal entanglement with no injury to hooking events with immediate or possible delayed mortality. For this reason, the numbers of sea turtle takes quantified in this report are not equivalent to mortalities.

3. Results

B/C ratios represent the magnitude of sea turtle interactions associated with a common weight of target fish catch. B/C ratios are expressed in a pictorial format in Figs. 1 and 2. The areas of the circles are proportional to the number of sea turtle takes per 190,000 kg of target fish (tuna or swordfish caught). Hawaii's tuna longline fishery, with the lowest B/C ratio in this comparison, establishes the benchmark of one sea turtle take per 190,000 kg of fish. The significant progress in this fishery in reducing sea turtle bycatch is depicted clearly in the comparison of B/C ratios

Table 1
Estimates of CPUE, sea turtle BPUE and bycatch to catch (B/C) ratios for Western Pacific longline fisheries targeting tuna/mixed species.

Longline fishery Operating within WCPFC convention area by flag, targeted fish, and general latitude	Hook depth and sea turtle populations impacted	CPUE Target fish mt/ 10,000 hooks	BPUE Sea turtle takes/ 10,000 hooks	B/C (BPUE/CPUE)
Hawaii (US): bigeye, yellowfin, albacore tuna; Sub-tropical central North Pacific	Hook depth: 43–400 m North Pacific loggerheads, western Pacific leatherbacks	1.9[a]	0.01[b]	0.005
Hawaii (US): swordfish; Sub-tropical and temperate central North Pacific (after 2004 management regime)	Hook depth: 21–70 m North Pacific loggerheads, western Pacific leatherbacks	9.7[c]	0.19[d]	0.02
Japan: bigeye, yellowfin tuna; Tropical Pacific fishery	Hook depth: 45–400 m Western Pacific greens, olive ridleys	3.60[e]	0.09[f]	0.025
Eastern Australia: swordfish, tuna, s. marlin Eastern Australia	Hook depth: 35–50 m Southwest Pacific loggerheads and greens	4.8[g]	0.24[h]	0.05
Taiwan: offshore fishery, bigeye, yellowfin tuna, billfish; Tropical Pacific fishery	Hook depth: 35–250 m Western Pacific greens, olive ridleys	3.30[i]	0.24[j]	0.073
China: bigeye, yellowfin tuna, billfish; Tropical Pacific Fishery	Hook depth: 35–120 m Western Pacific greens, olive ridleys	2.40[k]	0.24[j]	0.1

[a] Average of number of albacore, bigeye and yellowfin tuna/10,000 hooks for 2003–2005. 2005 average calculated from Western Pacific longline logbook summary for 1/2005 through 12/2005, vessels landing or based in Hawaii, tuna trips, *X* average weight of fish per species, 2005, from Russell Ito, Fisheries Monitoring and Socioeconomics Division, NOAA Fisheries PIFSC. 2003 and 2004 averages calculated from pp. 3–49, tuna trip CPUE (fish per 1000 hooks), pp. 3–49, Pelagic Fisheries of the Western Pacific Region 2004 Annual Report, Western Pacific Regional Fishery Management Council June 2005 *X* average weight of fish per species 2003 and 2004, from Russell Ito, Fisheries Monitoring and Socioeconomics Division, NOAA Fisheries PIFSC.

[b] Pacific Islands Regional Observer Program, Hawaii Deep-Set Longline Fishery Annual Status Reports 2003–2005, NOAA Fisheries PIRO.

[c] Average of 2004 and 2005 estimates. 2004 estimate calculated from WPRFMC, 2004. Pelagic fisheries of the western Pacific region, 2002 Annual Report. Honolulu, HI (average swordfish CPUE and average swordfish weight estimate for 2004, pp. 3–50 and Table 6 2005). 2005 estimate calculated from 2005 CPUE calculated from Western Pacific longline logbook summary for 1/2005 through 12/2005, vessels landing or based in Hawaii, swordfish trips *X* 2005 average swordfish weight estimate from Russell Ito, Fisheries Monitoring and Socioeconomics Division, NOAA Fisheries PIFSC.

[d] Sea turtle capture rates by the Hawaii swordfish longline fishery after regulations designed to reduce sea turtle interactions came into effect, May 3, 2004–March 19, 2006. Table 1, E. Gilman, D. Kobayashi, T. Swenarton, P. Dalzell, I. Kinan and N. Brothers. 2006. Efficacy and commercial viability of regulations designed to reduce sea turtle interactions in the Hawaii-based longline swordfish fishery. Western Pacific Regional Fishery Management Council, Honolulu, HI.

[e] Calculated from Table 2, 2001–2005 annual data longline vessels >20 GT), H. Matsunaga, H. Okamoto, K. Uosaki, K. Sato, Y. Semba and N. Miyabe. WCPFC-SC2-2006, National Tuna Fishery Report, Japan. Scientific Committee Second Regular Session, Western and Central Pacific Fisheries Commission, 7–18 August, 2006. Manila, Philippines.

[f] Calculated from 2001–2004 estimates of annual sea turtle takes (Table 7d) and fishing effort (Table 1b) in western tropical Pacific deep longline fisheries covered in the Secretariat of the Pacific Community observer data base. B. Molony, 2005. Estimates of the mortality of non-target species with an initial focus on seabirds, turtles and sharks. EB WP-1, 1st Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, WCPFC-SC1, Noumea, New Caledonia, 8–19 August 2005.

[g] Calculated from D. Bromhead, and J. Findlay. 2003. National Tuna Fishery Report. Tuna and billfish fisheries of the eastern Australian fishing zone and adjacent high seas. SCTB16 Working Paper NFR-2. 16th Meeting of the Standing Committee on Tuna and Billfish. Mooloolaba, Queensland, Australia. (Table 1, average of 1999–2002) by adjusting processed weight to whole weight ($PW/0.89 = WW$).

[h] C.M. Robins, S.J. Banche and S.R. Kalish, 2002. Bycatch of sea turtles in Pacific longline fisheries-Australia. Department of Agriculture, Fisheries and Forestry, Australia. 312pp.

[i] Calculated from 1993 to 2004 catch/effort statistics of Taiwan offshore longline fleet, Table 19, T. Lawson (Ed.), 2006. Draft Western and Central Pacific Fisheries Commission Tuna Fishery Yearbook 2005. Oceanic Fisheries Programme, Secretariat of the Pacific Community.

[j] Calculated from 2001 to 2004 estimates of annual sea turtle takes (Table 7d) and fishing effort (Table 1a) in western tropical Pacific shallow longline fisheries covered in the Secretariat of the Pacific Community observer data base. B. Molony, 2005. Estimates of the mortality of non-target species with an initial focus on seabirds, turtles and sharks. EB WP-1, 1st Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, WCPFC-SC1, Noumea, New Caledonia, 8–9 August 2005.

[k] Calculated from X. Liuxiong, 2002. National Report of China. SCTB15 Working Paper NFR-14. 15th Meeting of the Standing Committee on Tuna and Billfish, 22–27 July 2002. Honolulu, HI (Table 1, 3, average of 2000–2001).

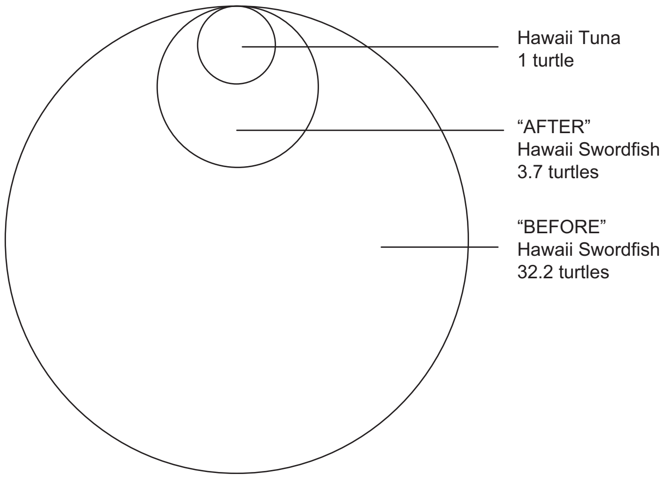

Fig. 1. Sea turtle bycatch to catch ratios in Hawaii longline fisheries (per 190,000 kg of catch). The benchmark of one turtle per 190,000 kg of fish is established by Hawaii's tuna longline sector. B/C ratios are compared before (1994–1999) and after (2004) management measures were implemented in Hawaii's swordfish longline sector to reduce sea turtle interactions.

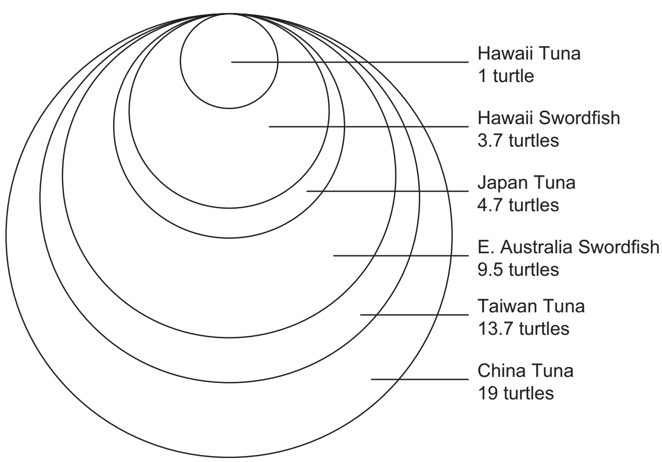

Fig. 2. Comparison of sea turtle bycatch to catch ratios in selected central and western Pacific pelagic longline fisheries (per 190,000 kg of catch). The benchmark of one turtle per 190,000 kg of fish is established by Hawaii's tuna longline sector.

"before" (1994–1999) and "after" new Federal regulations to reduce fishery impacts came into effect in 2004.

Circle diagrams (Fig. 2) were also used to compare the sea turtle B/C ratios of Hawaii's tuna and swordfish longline fisheries with those of major non-US longline fisheries operating in the western and central Pacific Ocean. The B/C ratios of the other fisheries were adjusted to the baseline Hawaii longline tuna catch weight (190,000 kg) for direct comparison of impacts per common weight of fish catch. The larger the area of the circle, the more sea turtle takes associated with every kilo of fish from that source.

For longline-caught tuna, Hawaii had a B/C ratio of 1 sea turtle interaction per 190,000 kg of fish catch compared with China's ratio of 19 interactions for the same quantity of tuna, based on the latter fleet's operational characteristics in the early 2000s. At that time, most hooks were deployed by China-flag longliners in the shallow "turtle layer" of the upper ocean. Since then, the China-flag longline fleet operating in Micronesia has converted to modern longline equipment that facilitates much deeper deployment of hooks. The present sea turtle bycatch by this fleet, therefore, is likely to be lower than the B/C ratio in Fig. 2.

4. Discussion

4.1. Limitations of B/C estimates

Hawaii longline fisheries are presently the largest source of observer data for Pacific sea turtle bycatch in longline fisheries. The high level of observer coverage produces reliable data on the species, numbers and severity of sea turtle interactions. In comparison, sea turtle bycatch in non-US longline fisheries in the central and western Pacific is poorly documented. Only preliminary estimates are possible and caution should be taken in making comparisons due to the low level of observer coverage and poor species identification of incidentally captured animals [4]. For these reasons, effort should be made to improve the quantity and quality of observer data used in calculating B/C ratios for non-US longline fisheries to document that sea turtle bycatch is being reduced under international fishery management regimes.

All takes of all sea turtle species are treated equally for the purposes of this B/C ratio analysis. Lumping is necessary because of the paucity of species-specific data from most observed longline fisheries outside of Hawaii. The impact of a turtle interaction varies considerably depending on the species, its condition after capture, its life stage and the status of its population. No distinction or weighting based on turtle species, life stage or population status could be made in the present study. Ideally this distinction should be made because an incidental capture and mortality of an adult from a severely depleted population, such as eastern Pacific leatherbacks, would be more significant than the mortality of a juvenile from a healthier population, such as Atlantic leatherbacks.

4.2. Utility of B/C ratios

B/C ratios can serve as an objective and measurable index within standards for sustainable seafood sourcing and marketing. The B/C ratio expresses impacts on sea turtles in terms of a standard fish weight. B/C ratios can also be used to address finfish bycatch and fishery impacts on other protected species equally well. Thus, it standardizes and allows for meaningful comparisons of different longline fisheries that harvest and market the same fish products (Fig. 2). B/C ratios are useful for monitoring progress in mitigating protected species interactions over time in a single fishery (e.g., Hawaii swordfish longline fishery). Clearly, Hawaii longline fishery products are the best choices among the fisheries compared for marketers with seafood sustainability standards and consumers who are concerned about pelagic longline fishery impacts on sea turtle populations.

5. Conclusion

As consumer concerns about the environmental impacts of fishing and the market need for practical and meaningful sustainable seafood purchasing standards increases, suppliers will need effective ways to distinguish their fishery products. With over 85% of the seafood consumed in the US now being imported [13], consumers face a growing challenge to differentiate seafood by country of origin, sustainable fishery practices and effectiveness of fishery management, as well as processing standards and seafood safety.

Sustainable seafood is produced by well-managed responsible fisheries that not only limit the fish catch to sustainable levels, but also control adverse ecosystem impacts including the incidental catch of sea turtles. Consumers and marketers of tuna and swordfish who share concerns about sea turtles want to know "Which source of fish is least harmful to sea turtle populations?" Bycatch-to-catch ratios, whether reported as a component of seafood sustainability standards, or when expressed as circle diagrams for easy comparison of suppliers, offer one way to answer this basic question.

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