Received: 6 & 24 October 2014

Status of billfish in large pelagic fisheries in Sri Lanka

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Sri Lanka has a well-established fishery for large pelagic fishery resources targeting tuna. The annual production of large pelagic was 123,872 mt in 2013 and of which tuna represented 74% of the total. Although there is no target fishery for billfish, Sri Lanka makes considerable contribution to the billfish production in the Indian Ocean. Billfishes make up to 10% 0f the total large pelagic landings. This shows that either the large pelagic fish production or the relative contribution of billfish have not been changed over the past decade.

Five species of billfishes have been identified in local commercial landings. This includes three species of marlins; black marlin (*Makaira indica*), blue marlin (*Makaira nigricans),* striped marlin *(Tetrapturus audax*), and two non-marlin species; the sailfish *(Istiophorus platypterus)* and the swordfish *(Xiphias gladius).* In catch composition, swordfish dominated at present making up to 44% while least represented by marlin, only 23%. However, marlin dominated the catch until late 90's and swordfish has increased in recent past may be a result of increased longline fishing for large tuna in deeper waters. Gillnet is still the dominating gear in billfish production followed by longline, while a small contribution comes from trolling and handline operation.

Catch statistics of billfish are provided separately by species and effort by gear. Lengths recorded are very poor in accuracy, especially for marlins and swordfishes as they are cut open at the sea for the purpose of storage. As such sufficient length-frequency data is not available.

Introduction

The total catch of tuna and tuna-like species in Indonesia has increased steadily since the early 1990's, especially the dramatic increase in the catches of tunas and/or tuna-like species unloaded in Jakarta, Cilacap and Benoa. The increase is related to the development of a domestic fleet in Indonesia, which is operating further offshore. The catch of billfish is generally is a by-catch or secondary catch of to the tunas. The catch of billfish is often poorly recorded, being lumped together in to single category, misidentified or the fish is discarded (Campbell *et al.,* 1998). Knowledge of Indian Ocean billfish biology and fisheries, the status of billfish species remains unclear due to lack of a targeted fishery on these stocks and uncertainties in the data available.
Fishery for tuna and tuna-like species is a major component in large pelagic fisheries in Indonesia. Indonesia has a well-established offshore/oceanic large scale tuna fishery (> 30 GT) and small scale tuna fisheries with fleet of locally designed and multi-day boats sailing up to even beyond the edge of the EEZ. Long line is main gear of large scale tuna fisheries whereas the small scale fishery is operating troll line, hand line or its combination. The production of tuna and tuna-like species tend to increase according to the recent statistics. The contribution of billfish to the fishery is significant, and the catch has increased considerably over the years highlighting their importance in the large pelagic/offshore fishery in Indonesia. The catch of billfish from Indonesia vessels has increased to over 400,000 MT in 2007 by all fleets in the Indian Ocean. Yet there is a general paucity of information on billfish, particularly from small-scale fisheries of the coastal states of the Indian Ocean.

Since the Implementation *of a Multilateral Catch Monitoring Program in 2002 involving domestic and foreign institutions,* has been breaking down by species of data record of tuna and billfish since 2003. Earlier, production of billfish are not in details as marlins are categorized in to a single group. Up till now no research has been carried out on billfishes, published information on billfish therefore is very limited. This group billfish includes Marlins, Sailfishes and Swordfishes. This paper inform the catches of billfish landed based on two main fishing port (Cilacap and Pelabuhanratu) in Indonesia and data sampled from a sampling site in Benoa, Bali and Jakarta.

Fisheries Data Collection System

To support the marine fisheries management and also being recognized that the country has a huge coverage of fishing areas, the government improved the area from 9 into 11 fisheries management area (Ministry Regulation, 2/2009). This regulation were decided in order to obtain a better documentation scheme on catch and exploitation
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levels based on types of ecosystem and their fisheries. This also include to develop fleet monitoring and controlling system. Based on the new regulation, Indian Ocean waters of Indonesia grouped in two management area *i.e.* western part of Sumatera and southern part of Java and Lesser Sunda. The areas is showed in Figure 1.
Fig

Indonesia has had a National Fisheries Data Collection System for marine fisheries since 1978 – a system that emerged from a collaborative program between the Government of Indonesia, the United Nations Development Programme, and FAO. The design, development and implementation of a standard set of surveys and reporting methods across all of Indonesia's provinces was done by Dr Tadashi Yamamoto, a fisheries statistician employed by FAO, in collaboration with Directorate General of Fisheries (now Directorate General of Capture Fisheries).
With respect to marine fisheries, the system was designed to have two primary outcomes: 1) Nation-wide statistics on annual production for all species groups fished, both at the industrial and artisanal levels of fishing activity, and 2) Nation-wide annual inventories of the number of fishing units (households, companies, operators) and number, size, and gear-type of fishing vessels involved in the fishing activities at both levels in all provinces. These statistics have been and continue to be published by the Directorate General of Fisheries (now DGCF) as the annual report "Statistik Perikanan Tangkap Indonesia" (= Statistics of Capture Fisheries of Indonesia). These reports also include similar statistics for inland "openwater" fisheries. The surveys and censuses were, and still are, coordinated at a national government level by DGCF (in collaboration with the Central Board of Statistics), but involve data collection and reporting by provincial, district, and subdistrict government offices. The fundamental design and procedure of the national system are summarised below in Figure 2.
Similar methodological approach was used to evaluate the whole area of fisheries management. Since there are limited capacities to do independent fisheries data, the existing available data to describe the exploitation status were explored through annual statistical provincial data with assumption all the catch and effort data were regularly

recorded by enumerator at sampled landing places.

Billfish Production

Annual production of billfish in Indian Ocean waters of Indonesia (Westernpart of Sumatera and Southernpart of Jawa and Lesser Sunda) is fluctuated in 2004 to 2007 period. Total catch of swordfish and black marlin shown tend to increase. Among billfish, the most common species in the catches is the swordfish, while striped marlins are caught in small quantities. The billfish production is shown in Figure 4.

Figure 4. Billfish production from Indian Ocean Waters of indonesia 2004-2007

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Figure 5 and 6 shown the annual billfish landed in two main fishing port in western part of Java *i.e.* Cilacap and Pelabuhanratu. Based on port statistic fisheries most of unload vessel in Cilacap was tuna longline. Black marlin dominated production of billfish landed in Cilacap.While in Pelabuhantu, beside longline vessel, since 2005 troll line fishery have been contributed to the billfish production. Similar with Figure 4, the annual production from both fishing port were fluctuated.

Figure 5. Billfish landed in Cilacap Fishing Port 2002-2008

Figure 6. Billfish landed in Pelabuhanratu Fishing Port 2002-2008

Catch Monitoring of Billfish

Five species of billfishes have been identified in landing places. This includes 3 species of marlins; black marlin (BLM) (*Makaira indica*), blue marlin (BLZ) (*Makaira mazara),* striped marlin (MLZ) *(Tetrapturus audax*), two species non-marlin species are the sailfish *(Istiophorus platypterus)* and the swordfish *(Xiphias gladius). C*atch monitoring on billfish fishery conducted by samplers in Jakarta, Cilacap and Benoa as apart of tuna landing sampling program. Samplers record every day the names of the longliners unloading catches and the processing plants through which the catches unloaded go. By-catch fish are not always weighed or not weighed individually. Although the samplers do their best to measure the length of the specimens whose weight is not available. Thus, the total number of specimens

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and total weight of the aggregate are recorded. The identification of marlins is in some cases difficult, especially when the fish are frozen and/or processed. Thus, the three species of marlins are usually tailed. These fish are, therefore, recorded using the closest aggregate. Available data record of billfish from two sampling site (Jakarta and Benoa) is present figures below. Figure 7 and 8 shown that swordfish is the dominant fish sample followed by sailfish, blue marlin, and black marlin.

Figure 7. Number of fish sampled by species in Benoa

Figure 8. Number of fish sampled by species in Jakarta

Length frequency data sampled from two fishing port (Benoa and Jakarta) of each species of billfish is presented in Figure 9 – 14 below. Minimum length of black marlin, blue marlin and swordfish sampled in Benoa are 111 cm, 96 cm and 70 cm and maximum length are 235 cm,230 cm and 245 cm respectively. While, minimum length of swordfish, sailfish and billfish sampled in Jakarta are 41 cm, 70 cm and 101 cm, and maximum length are 190 cm, 210 cm and 270 respectively. Leng frequency distribution of billfish present in Figure 9-14.

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Tabel 9. LF distribution of black marlin sampled in Benoa Tabel 10. LF distribution of blue marlin sampled in Benoa

Tabel 11. LF distribution of swordfish sampled in Benoa Tabel 12. LF distribution of swordfish sampled in Jakarta 2002-2005

Tabel 13. LF distribution of sailfish sampled in Jakarta 2002-2005 Tabel14. LF distribution of billfish sampled in Jakarta 2002 - 2005

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Current and Future Activities

Indonesia, aware of the importance of obtaining precise catch estimates for the assessment and management of billfish stocks, due to provide complete estimates of catches new data collection systems introduced since 2002. Undertake trial to implement new system to increase sampling coverage of landing places would be enhance the representative catches data. Training of data recording procedure for port sampler is needed to provide accurate data include to eliminate mis-indentification of billfish.

References

Anon, 2008. Indonesian Capture Fisheries Statistic 2007. Directorat General of Capture Fisheries, MOMAF, Indonesia.

Anon, 2009. Fisheries Statistic of Cilacap Fishing Port 2008

Anon, 2009. Fisheries Statistic of Pelabuhanratu Fishing Port 2008

PROBLEM STATEMENT

All food production systems, including fishing, have associated ecological costs, although these may not be fully recognized or acknowledged. Rising awareness of such costs is shifting attention from the traditional management of single species or species groups to a new perspective known as ecosystem-based fishery management (FAO, 2001) or ecosystem approach to fisheries (FAO, 2003). This approach refers to a holistic view of the interrelationships between physical and living components (including people) on various geographic and temporal scales. It recognizes the importance of interactions among different fish species that are targeted or taken incidentally and the possible effects of fishing (direct and indirect) on habitat or on other species (fish and non-fish) that occupy the habitat.

The ecosystem perspective has heightened concern about the possible impacts of fisheries bycatch. As a consequence, incidental catches of non-target fish species and protected marine mammals, seabirds, and sea turtles have become a very important factor in the management of some fisheries (Hall, 1996). Bycatch is neither a new issue nor a new problem. Pelagic fisheries bycatch became highly visible because of cases involving charismatic species such as dolphins and sea turtles (Hall et al., 2000). The eastern Pacific tuna purse seine fishery-dolphin interactions in the 1960s marked the beginning of such concerns (Hall, 1996). This was followed by the well-publicized debate over the use of high seas drift nets that entangled huge numbers of non-target fish, marine mammals, sea turtles, and sea birds in the late 1980s (Hinman, 1998).

Some environmental advocacy groups specifically campaign against fish bycatch in U.S. fisheries (e.g., Dobrzynski et al., 2002). Bycatch associated with target fish is one of the criteria used in the Monterey Bay Aquarium's Seafood Watch program for advising consumers to make environmentally friendly seafood purchasing decisions (www. montereybayaquarium.org).

A 1995 United Nations agreement on conserving highly migratory fish stocks includes a directive to reduce bycatch (Doulman, 1995). In 1996, the U.S. Congress passed legislation amending the 20-year old Fishery Conservation and Management Act to include, for the first time, an explicit mandate to “minimize bycatch and, to the extent bycatch cannot be avoided, minimize the mortality of such bycatch” (Hinman, 1998). However, limited information on the stock condition of incidentally-captured species often prevents bycatch data from being compared across fisheries and considered in a reasonable biological or stock context (Hoey and Moore, 1999).

The ecological implications of discarding incidentally captured but unwanted animals are not well understood; however, the practice is perceived by resource managers and the
general public as wasteful. Dead biological matter discarded in the ocean is a food subsidy
and, thus, it is presumably quickly recycled. The effects may be considered positively or negatively depending on the values placed on different animals that may benefit from this
food supplement and its redistribution (Harris and Ward, 1999).

1

It is clear that the impact of pelagic longline fisheries on populations of incidentallycaptured
sea turtle or finfish species, and thus the magnitude of bycatch as a management issue, depends on the following.

• The rate of capture; and
• The proportions that are released after capture alive wi

Catch to Bycatch Ratios: Comparing Hawaii's Longline Fisheries with Others

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Acknowledgments

The authors would like to acknowledge the writings and ecological thinking of Martin Hall (Inter-American Tropical Tuna Commission) that have been a source of inspiration and guidance for this research. We would also like to thank the many industry members and scientists who provided us with the information needed to develop the pelagic longline
fishing typologies. We would not have been able to develop finfish bycatch per unit effort
estimates (BPUE) for Hawaii pelagic longline fisheries without assistance from Kitty Simonds and the staff of the Western Pacific Regional Fisheries Management Council,

supported by the Pacific Islands Science Center analysis of the Hawaii longline observer
database compiled by the Pacific Islands Regional Office. We are also indebted to Peter Williams and Tim Lawson of the Secretariat of the Pacific Community and Tim Park of the
Micronesian Maritime Authority for their contributions of fisheries data to the project. This research was funded by Cooperative Agreement Number NA17RJ1230, between the Joint Institute for Marine and Atmospheric Research (JIMAR) and the National Oceanographic and Atmospheric Administration (NOAA). The views expressed herein are those of the authors and do not necessarily reflect the view of NOAA or any of its subagencies.

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ABSTRACT

The ecological impacts of pelagic longline fisheries vary with when, where, and how the mainline and hooks are set. The quantity and species composition of longline targeted and
incidental catch are strongly influenced by gear configurations, especially the depth of hooks.
Hawaii pelagic longline fisheries are sometimes characterized as having “high bycatch.” To
assess this statement quantitatively, the present study examined diverse longline fisheries,
including those in Hawaii, that supply or have the potential to supply the same pelagic fishery products to U.S. markets. Incidental catch rates of sea turtles and finfish bycatch

were estimated for the fisheries where data were available. The term “bycatch” is defined
as fish released at sea dead or with a poor chance of survival. Indices of bycatch per unit
effort (BPUE) and catch per unit effort (CPUE) were calculated from reported target catch,
effort and incidental catch data for these fisheries. Catch to bycatch ratios (C/B ratio)
were calculated by dividing CPUE by BPUE. C/B ratios provide a standardized index that
allows 1) scaling of pelagic longline bycatch rates from low to high; and 2) comparison of
Hawaii’s pelagic longline fisheries with others on this quantitative scale.

The major finding of this research is that Hawaii’s tuna longline fishery has a lower C/B ratio of sea turtles and finfish waste (except for longnose lancetfish) compared to most competing pelagic longline fisheries studied. Claims of high rates of incidental catch of sea turtles and finfish bycatch (waste) associated with Hawaii tuna longline fishing are therefore, incorrect. The extraordinary amount of regulation and monitoring of Hawaii longline fisheries and the rich source of data they provide for resource assessment and technological solutions to bycatch issues, qualify them as a model for fisheries management.

The positive attributes of the Hawaii fishery can be considered a “value-added” component
of Hawaii longline products to “brand” and differentiate them from non-Hawaii longline products that have significantly higher associated bycatch.

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1. PROBLEM STATEMENT

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these may not be fully recognized or acknowledged. Rising awareness of such costs is shifting attention from the traditional management of single species or species groups to a new perspective known as ecosystem-based fishery management (FAO, 2001) or ecosystem approach to fisheries (FAO, 2003). This approach refers to a holistic view of the
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The ecological implications of discarding incidentally captured but unwanted animals are not well understood; however, the practice is perceived by resource managers and the general public as wasteful. Dead biological matter discarded in the ocean is a food subsidy and, thus, it is presumably quickly recycled. The effects may be considered positively or negatively depending on the values placed on different animals that may benefit from this food supplement and its redistribution (Harris and Ward, 1999).

1

It is clear that the impact of pelagic longline fisheries on populations of incidentallycaptured sea turtle or finfish species, and thus the magnitude of bycatch as a management issue, depends on the following.

- The rate of capture; and
- The proportions that are released after capture alive with a good chance of survival versus dead or mortally injured.

2. PURPOSE AND ORGANIZATION OF STUDY

Hawaii pelagic longline fisheries are sometimes characterized as having high bycatch. There are two problems with this generalization: 1) "high" is not measured according to any quantitative scale; and 2) some definitions of finfish bycatch include non-target fish species that are released alive after capture, a conservation practice known as "catch and release" in recreational fisheries. The specific tasks of the present research are as follow.

- Clarify the term bycatch in relation to Hawaii longline fisheries (Section 3).

• Profile the heterogeneous fishing gear configurations and practices of selected pelagic longline fleets worldwide (Section 4).
• Assess the general factors that affect the incidental take of sea turtles (Section 5.1) and of unwanted fish (Section 5.2).
• Estimate target fish CPUE and incidental catch of sea turtles (BPUE, number of animals taken per unit of effort) (Section 6.1) in selected pelagic longline fisheries.
• Estimate target CPUE and BPUE of wasted fish (weight of animals discarded dead or dying per unit of effort) (Section 6.2) in selected pelagic longline fisheries.
• Compare the Hawaii longline fisheries with others in terms of C/B ratios of sea turtles (Section 7.1) and of wasted fish (Section 7.2).
• Discuss the study results and make recommendations for fishery managers to consider (Section 8).

3. DEFINITION OF BYCATCH

Finfish bycatch in U.S. fisheries has negative connotations because the word is perceived by the general public to be equivalent to “mortality” and “waste.” Some usages of the term fail to distinguish animals released alive and vigorous after incidental capture from those that are dead or dying.

A clear definition of terms is a prerequisite for objective study of bycatch. The conceptual framework of Hall (1996) is useful for considering the possible fates of animals captured in fisheries (Figure 1). According to this definition, bycatch is limited to non-viable (i.e., dead or mortally injured) releases of target or non-target fish and prohibited species such as sea turtles, seabirds, or marine mammals. Fish that are caught and retained are not bycatch because they are used. Nor does bycatch include fish that are alive and viable (i.e., likely to survive) when released after incidental capture. Under the Hall definition, bycatch is clearly synonymous with waste.

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However, there are a variety of other interpretations of the term bycatch. The Magnuson-Stevens Fishery Management and Conservation Act (MSA), under which fisheries are managed in U.S. waters, defines bycatch as animals that are caught but not sold or kept for personal use. Included are fish and non-fish species that are released alive or dead, as well as any that are injured or killed as a result of direct contact with fishing gear. The latter group includes fish that are stripped from fishing gear by predators before they can be brought aboard fishing vessels as well as any species injured or killed by lost or discarded fishing gear (“ghost fishing”) (WPRFMC, 2003).

Sea turtle “takes” in Hawaii longline fisheries include unintentional interactions with fishing line and/or hooks, both lethal and non-lethal. A sea turtle take is not equivalent to a kill. Pelagic longline fisheries impact sea turtle populations if incidentally-captured animals die, not if they are released after incidental capture and survive. The mortality of sea turtles incidentally-caught in pelagic longline fishing combines immediate mortality and post-release mortality of injured animals. Post-release mortality of incidentally-caught sea turtles has not been estimated for most pelagic longline fisheries. There is little agreement among scientists and managers about the percentages of deeply-hooked and lightly-hooked sea turtles released alive that are likely to suffer delayed mortality as a result of interactions with longline gear. Until there are better estimates of post-release mortality, the analysis of mortality impacts has to be based on non-lethal and lethal sea turtle takes rather than mortalities alone.

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Figure 1. Possible fate of animals, including bycatch, captured by pelagic longline fisheries.

In the Hawaii longline fishery relatively large quantities of finfish are released alive after incidental take but there is little to no information on post-release mortality (WPRFMC, 2003). By including fish released alive as bycatch, the MSA places a negative connotation on this beneficial practice. The Act provides an exception from this provision for some recreational catch-and-release fisheries but such exceptions have not yet been established for any fisheries in the western Pacific region (WPRFMC, 2003). The MSA is contradictory in that release of live fish may not be bycatch in some U.S. recreational fisheries but is always bycatch in U.S. commercial fisheries.

Other fisheries managers define finfish bycatch as all incidentally caught non-target species (Harris and Ward, 1999), whether the incidental catch is retained or not, without considering the potential value as byproducts of fishing. The same definition of bycatch is used by the Oceanic Fisheries Programme of the Secretariat of the Pacific Community (SPC) to describe non-target species caught in western and central Pacific tuna fisheries (Williams, 1996) “Any catch of species (fish, sharks, marine mammals, turtles, seabirds, etc.) other than the target species. ‘Incidental catch’ can be regarded as synonymous.…” (Bailey et al., 1996: 2.1).

Two components of catch are combined in this definition: the non-target species catch that are retained and the non-target species that are discarded (Williams, 1996). The latter

definition is confusing because "…it mixes what is waste with what is an additional source
of income to the fishery" (Hall, 1995: 41).

4. TYPOLOGY OF PELAGIC LONGLINE PRACTICES

Pelagic longline fisheries operate in an area of more than two-thirds of world's oceans (about
50 million square nautical miles) (FAO, 2001). Some people regard pelagic longlining as a "relatively environmentally friendly" fishing method (Anon., undated), whereas others suggest that "the best way to describe fishing with a longline is laying an underwater minefield" (Hinman, 1998) or they view pelagic longlining as "…one of the most lucrative and perhaps destructive fisheries in the world" (Crowder and Myers, unpublished research
proposal to the Pew Charitable Trusts). The problem with these generalizations is that pelagic longlining is not a homogenous method of fishing and its environmental impacts can vary significantly with specific gear configurations and fishing practices.

The general design of pelagic longline gear is relatively simple (Figure 2). Operating characteristics such as area and season fished, time of set, ocean temperature, fishing depth,
bait, and other factors significantly affect the catch rates and mix of species caught (Hoey
and Moore, 1999).

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Figure 2. General design of pelagic longline gear.

Table 1 describes the diversity in longline gear, deployment, and fishing tactics recorded in
the present research and discusses the possible implications for the incidental catch of sea
turtles and finfish bycatch. Tables 2-6 profile and compare the distinguishing characteristics
of the following pelagic longline fisheries.

Central and Western Pacific Ocean Eastern Pacific Ocean
Australia California
China Chile
Hawaii Costa Rica
Japan Mexico
Samoa
Taiwan **Atlantic Ocean**
Brazil
Indian Ocean Namibia
Sri Lanka South Africa

Detailed profiles are limited to longline fisheries that, like Hawaii, produce fresh pelagic fish or have that potential. The operating characteristics of Asian distant-water deepfreezing
longline fleets are discussed in relation to potential incidental catch of sea turtles
but no detailed profiles are provided in the present study.

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Table 1. Possible implications of pelagic longline operational characteristics for the

incidental catch of sea turtles and finfish bycatch.
Characteristic Diversity Recorded in
Present Study
Possible Implications
for Sea Turtle Bycatch
Possible Implications
for Finfish Waste
Target species Yellowfin, bigeye,
albacore, bluefin tuna,
swordfish, marlin,
mahimahi, shark
When shallow-water fish
are targeted, especially
mahimahi and shark,
more hooks are set in the
shallow “turtle layer.”
When deep-water
fish, especially bigeye
and albacore tuna,
are targeted, a high
percentage of unwanted
fish hooked in the
thermocline layer may
not survive due to
changes in pressure,
light and ocean
temperature when
hauled to the surface
Hook soak period Day or night Unknown Different mixes of
incidental finfish species
are caught in day and
night soak periods.
Mainline material Nylon rope or
monofilament
Unknown, although sea
turtles may be attracted
to and follow mainline.
Unknown
Mainline shooter With shooter, the line
settles deep because line is
slack; without shooter, line
settles shallow because it
is taut.
Deep sets catch 10 times
fewer sea turtles than
shallow sets.
Deep sets incidentally
catch finfish species from
thermocline stratum;
shallow sets incidentally
catch finfish species
from mixed layer.
Hooks/set 400 to 3000 No effect on incidental
capture rate.
No effect on incidental
capture rate.

Leader material Monofilament; 1.5 mm
wire; or 2.5 mm wire (to
target shark); attached to
branch line with or without
leaded swivels
Unknown Higher percentage of
incidental finfish catch
retained on wire leader
Bait Saury, sardine, mackerel,
pilchard (to target tuna);
squid to target mahimahi,
swordfish; skipjack tuna
and mackerel to target
shark
Squid bait more likely
to result in incidental
capture of loggerhead
turtles than other bait
types. Blue-dyed squid
may reduce incidental
capture of green and
loggerhead turtles.
Different bait types
presumably catch
different mixes of
incidental finfish
species.
Lightsticks None; every hook or every
few hooks
Used in shallow sets.
Some sea turtle species
foraging at night may be
attracted to lightsticks
or certain colors of
lightsticks, confusing
them for prey.
Used in shallow sets.
May affect species mix
of incidental finfish
catch in mixed layer.
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**Characteristic Diversity Recorded in
Present Study**
**Possible Implications
for Sea Turtle Bycatch**
**Possible Implications
for Finfish Waste**
Hook type Ring hook; J hook; circle
hook
Large circle hooks
less likely to hook
loggerhead and
leatherback turtles than
J-hooks.
Hook type presumably
affects species mix of

incidental finfish catch.
Float line length 0 to 40m Longer float lines are associated with deeper hook depths. Deep sets incidentally capture 10 times fewer sea turtles than shallow sets.
Longer float lines are associated with deeper hook depths. Deep sets incidentally capture finfish species from the thermocline stratum, whereas shallow sets incidentally capture finfish species from the mixed layer.
Branch line length 5 to 30m Large branch lines may allow hooked or entangled turtles to reach the ocean surface to breathe.
Longer branch lines may increase the percentage of finfish (target and non-target) that are alive when retrieved.
Minimum depth fished
5 to 45m Shallow minimum depth places larger no. of hooks set in the shallow "turtle layer," resulting in higher sea turtle capture rates than deeper minimum depth.
Shallow minimum depth produces incidental finfish catch from the mixed layer.
Range of depth fished
5 to 400m Deep range of fishing significantly reduces sea turtle capture rates compared to shallow range of fishing.
Deep range of fishing produces incidental finfish catch from the thermocline layer in a weak condition for survival if released after capture.
Hook soak time 6 to 20 hrs. Longer period, combined with shallow

depth of fishing,
increases possibility
of incidental sea turtle
capture.
During longer period,
some incidentallycaught
finfish will fall
off line or be lost to
predators and, thus,
not be accounted for in
observer data.
Treatment of catch Iced; refrigerated seawater;
frozen
No effect Bycatch rate may be
affected by storage and
marketing options for
the catch.
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Table 2. Typical operating characteristics, Western Pacific deep-set fresh tuna longline fisheries.

Vessel Flag U.S. (Hawaii)[1] Samoa[2] Japan[3]
Target species Bigeye, yellowfin tuna Albacore tuna Bigeye, yellowfin tuna
Hook soak period Day Day Day
Mainline material Monofilament Monofilament Multi-strand hard nylon
Mainline shooter Yes Yes Yes
Hooks/set 2500 2700 2400
Leader Wire, monofilament Monofilament Monofilament
Bait Saury, sardine Sardine, pilchard Saury, mackerel
Lightsticks No No No
Hook type 3.6 mm Asian ring hook;
65 gm weight
< 1m from hooks
Circle hook 15/0 Asian ring
Hooks between floats 18-30 30-35 15-20
Float line length 30 m 27 m 20-40 m
Branch line length 13 m 13 m 25-30 m
Minimum depth fished[4] 43 m 40 m 45 m
Range of depth fished 43-400 m 40-180 m 45-400 m
Hook soak time 10-12+ hrs 8 hrs 10-12 hrs
Treatment of catch Iced (freshwater) Frozen brine for
albacore; freshwater ice
for yellowfin, bigeye
tuna.
Refrigerated seawater

[1] Pacific Ocean Producers, Catalog 2004 and personal communications; Baird (2001); National Marine Fisheries Service Honolulu Laboratory, Fishery Monitoring and Economics Program, unpubl. information; Gilman et al. (2002).
[2] Pacific Ocean Producers, Tony Costa, pers. comm. with P. Bartram, Jan. 17, 2003.
[3] Itano (2001); Park (2001; 2002); P. Bartram, interviews with Japanese longline captains and transshipment agents in Guam, various dates 1998-present. Information is specific to fresh tuna transshipment fleets operating from Pacific island bases.
[4] After Park (2002) = float line length + branch line length
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Table 3. Typical operating characteristics, Western Pacific shallow-set, mixed-species longline fisheries.

Vessel Flag U.S. (Hawaii)[1] Taiwan[2] China[3] Australia[4]
Target species Swordfish, bigeye

tuna
Bigeye, yellowfin
tuna, billfish
Bigeye, yellowfin
tuna
Bigeye, yellowfin
tuna, swordfish,
striped marlin
Hook soak period Night Mostly night; day
when live milkfish
bait used to target
YF
Night 80% night; 20% day
Mainline material Monofilament Nylon rope Nylon rope Monofilament
Mainline shooter No No No 50% yes; 50% no
Hooks/set 800-1000 1000-1500 800-1200 900-1100
Wire leader No No 1.5 mm (when
targeting mixed
species)
10% wire; 90%
monofilament
Bait Squid Squid to target
BE; Mackerel, live
milkfish to target
YF
Squid, mackerel Squid
Lightsticks Yes No No Yes
Hook type Mustad #9/0 J hook Asian ring Asian ring 3.4 Asian ring 3.4, 3.6;
17/0 Japanese circle
Hooks between floats 2-5 4-5 4-5 8
Float line length 8-10 m 10-25 m 10-32 m 15 m
Branch line length 13-17 m 25 m 25 m 20 m
Minimum depth fished[5] 21 m 35 m 35 m 35 m
Range of depth fished 21-70 m 35-250 m 35-120 m 35-50 m
Hook soak time Night (10-11+ hrs) 12 hrs. 10-11 hrs. 8-12 hrs.
Treatment of catch Ice (saltwater
for swordfish;
freshwater for other
catch)
Refrigerated
seawater
Ice (freshwater);
Refrigerated
seawater
Ice slurry

1 Historic Hawaii swordfish fishery (terminated mid-2001 under Federal regulations). Pacific Ocean Producers, Catalog 2004 and personal communications; Baird (2001); National Marine Fisheries Service Honolulu Laboratory, Fishery Monitoring and Economics Program, unpubl. Information; Gilman et al. (2002). J hooks and squid bait are prohibited and only large circle hooks and mackereltype
bait are permitted under present NMFS regulations for the reopened Hawaii swordfish fishery.

2 Park (2001; 2002); P. Bartram, interviews with Taiwanese longline captains and transshipment agents in Guam, various dates 1998-
2002; P. Bartram interview with Marshall Islands' Taiwan longline fleet manager January 2003 and personal observations at Marshall
Islands Marine Resources Authority's tuna transshipment base, Majuro, Republic of the Marshall Islands, various dates 2003; P. Bartram interviews with Taiwan fleet managers and personal observations at Palau International Traders International and Palau Marine Industries Corp. tuna transshipment bases, October 2003. Information is specific to fresh tuna transshipment fleets operating from Pacific island bases.

3 Park (2001; 2002); P. Bartram, interviews with Chinese longline captains, fleet managers and transshipment agents at Palau International Traders Inc. tuna transshipment base and Marshall Islands Marine Resources Authority's tuna transshipment base, Majuro, RMI, various dates 2003; and personal observations aboard F/V Clearwater I, August 2003. Information is specific to fresh tuna transshipment fleets operating from Pacific island bases.

4 Pacific Ocean Producers, Tony Costa, pers. comm. with P. Bartram, Sept. 24, 2003.

5 After Park (2002) = float line length + branch line length

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Table 4. Typical operating characteristics, Indian Ocean shallow-set mixed-species longline fisheries.

Vessel Flag	**Taiwan and China (landing in Sri Lanka)**[1]
Target species	Swordfish, tuna
Hook soak period	Night
Mainline material	Monofilament
Mainline shooter	No
Hooks/set	800-1500
Wire leader	No
Bait	Mackerel, squid
Lightsticks	No
Hook type	#6/0 J
Hooks between floats	5-10
Float line length	30-40 m
Branch line length	22 m
Minimum depth fished[2]	52 m
Range of depth fished	52-300 m
Hook soak time	8-12 hrs.
Treatment of catch	Refrigerated seawater (-1 to -2° C)

[1] R. Fernando, Tropic Frozen Foods Ltd, Sri Lanka, pers. comm. with P. Bartram, April 14, 2004.
[2] After Park (2001) = float line length + branch line length

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Table 5. Typical operating characteristics, Eastern Pacific shallow-set swordfish and mixed-species longline fisheries.

Vessel Flag U.S.
(California)[1]
Chile[2] **Mexico**[3] **Taiwan**[4]
(landing in Costa
Rica, Panama)
Costa Rica
(artisanal)[5]
Target species Swordfish Swordfish Swordfish Billfish, bigeye,
yellowfin tuna, shark
Mahimahi, tuna
Hook soak
period
Night Night Night Night Mahimahi—day;
Tuna—night
Mainline
material
Monofilament Monofilament Monofilament Nylon rope Monofilament
Mainline
shooter
No No No No No
Hooks/set 800 1100 800-1000 1000-1200 400-800
Wire leader No No No >2.5 mm when
targeting shark
No
Bait Squid Squid Squid Squid (mackerel,
skipjack tuna when
targeting shark)
Squid
Lightsticks Yes Yes Yes No No
Hook type Mustad #9/0 J
hook
Mustad #9/0 J
offset; 30 gm
weight above

hook
Eagle Claw
L9014
Asian ring Circle hook
Hooks between
floats
2-5 5 5 4-5 4-5
Float line
length
8-10 m 10 m 16 m 10 m when targeting
shark
0-6 m
Branch line
length
13-17 m 10 m 14 m 10 m when targeting
shark
5-7 m
Minimum
depth fished[6]
23 m 20 m 30 m 20 m when targeting
shark
5 m
Range of
depth fished
21-70 m 20-45 m 30-200 m 20-30 m when targeting
shark
5-20 m mahimahi
25-50 m billfish
Hook soak
time
10-11+ hrs 6-8+ hrs 10-12 hrs 10-12 hrs 12+ hrs
Treatment of
catch
Iced (saltwater
for swordfish;
freshwater for
other catch)
Iced
(freshwater)
Iced
(freshwater)
Refrigerated seawater Iced (freshwater)

[1] Pacific Ocean Producers, Catalog 2004 and personal communications; Baird (2001); National Marine Fisheries Service Honolulu Laboratory, Fishery Monitoring and Economics Program, unpubl. information. NMFS regulations to prohibit shallow set longline fishing east of 150° W longitude went into effect April 12, 2004, effectively closing the California-based shallow set longline fishery.
[2] Describes high-seas domestic longline fleet of approximately 15 vessels. Sources: Luis Vares, Patron De Pesca Longline, pers. comm. with J. Kaneko and P. Bartram, Nov. 21, 2002; Weidner and Serrano (1997).
[3] Jorge Romano, Pesquera Integral Isla Bonita, pers. comm. P. Bartram, Nov. 22, 2002.
[4] Assumes eastern Pacific operational characteristics similar to those in western Pacific from P. Bartram interviews with Taiwan longline vessel agents, Majuro and Palau, 2003. The Taiwan-flag longline fleet landing in Costa Rica targets mixed species but harvesting of sharks for fins is a crucial part of its economic strategy (PRETOMA, 2003).
[5] Arauz et al. (1999); Arauz (2000, 2001).
[6] After Park (2001) = float line length + branch line length
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Table 6. Typical operating characteristics, Atlantic shallow-set swordfish and mixedspecies
longline fisheries.

Vessel Flag Brazil[1] **South Africa**[2] **Namibia**[3]
Target species Swordfish, sharks Swordfish, tuna Swordfish, tuna, other
large pelagics, including
shark
Hook soak period Night Night Night

Mainline material Monofilament Monofilament Monofilament
Mainline shooter No No Some vessels yes; some no
Hooks/set 1000 1500 1400
Wire leader No No Yes
Bait Squid, chub, mackerel,
sardines
Squid Squid, mackerel
Lightsticks Yes Yes Mackerel bait yes; squid
bait no
Hook type Mustad #9/0 J; 75 gm
weight above hook
Mustad #9/0 J; 30 gm
weight above hook
Mustad #9/0 J
Hooks between floats 5-6 4 5
Float line length 18 m 15-30 m 9 m
Branch line length 16 m 12-18 m 15 m
Minimum depth fished[4] 34 m 27 m 24 m
Range of depth fished 34-80 m 27-50 m 24-100 m
Hook soak time 10-11+ hrs. 10-11 hrs. 20 hrs.
Treatment of catch Iced (freshwater) Iced (freshwater) Blast frozen

[1] T. Neves, Albatross Project, Environmental Secretariat of Sao Paulo State, Brazil, pers. comm. with J. Kaneko, Feb. 17, 2003; data obtained from longline skippers and Weidner and Arocha (1999).
[2] P. Nichols, Ministry of Fisheries and Marine Resources, Namibia, pers. comm. with J. Kaneko, June 14, 2003.
[3] P. Nichols, Ministry of Fisheries and Marine Resources, Namibia, pers. comm. with J. Kaneko, June 14, 2003.
[4] After Park (2001) = float line length + branch line length

5. FACTORS AFFECTING INCIDENTAL CATCH RATES OF PROTECTED SPECIES AND FINFISH BYCATCH IN PELAGIC LONGLINE FISHING

Operating characteristics ultimately determine the incidental catch rate of protected species,
finfish bycatch and species composition in pelagic longline fisheries. Bycatch rates depend
on how gear is configured, where and when it is set in relation to the habitat, and distribution
and behavior of these species.

5.1 Sea Turtles

Incidental catch of sea turtles occurs when feeding animals opportunistically encounter baited longline hooks or when they are accidentally entangled with longline gear. These interactions occur during the pelagic periods of sea turtles' lives when they are migrating
through the open ocean to and from inshore feeding or breeding/nesting habitats. Some species of sea turtles have more pelagic habits than others. Sea turtles rely on their visual
senses in their search for food and need to surface at regular intervals to breathe. Some
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species also exhibit a preference for distinct thermal regimes. These basic attributes have
implications for the likelihood of potential interactions with pelagic longline fishing gear and the outcomes of those interactions (Oceanic Fisheries Programme, 2001).
Seasonal aggregations of sea turtles occur in the proximity of nesting beaches, whereas

densities are expected to be significantly lower during the solitary pelagic phase. Fishing in proximity to nesting aggregations should be expected to have greater potential for sea turtle interactions than in the open ocean, where turtle density is lower (Segura and Arauz, 1995).

Observer-reported encounters in the Secretariat of the Pacific Community (SPC) statistical area clearly show that longline fisheries in the western tropical Pacific (10° N–10° S latitude) have far more sea turtle interactions than in the western sub-tropical Pacific (10° S–35° S) or western temperate Pacific (35°–45° S) (OFP, 2001). Unfortunately, a large proportion of observed sea turtle encounters in the SPC statistical area could not be identified to the species level. Green turtles and olive ridley turtles constituted the majority of sea turtles identified to the species level but this should not be taken as indicative of the relative sea turtle composition within the incidental catch of longline fisheries. The higher latitude distribution of loggerhead turtles, however, makes it highly unlikely that there are any takes of this species in SPC observer records for the tropical western Pacific.

Several characteristics of pelagic longline gear and deployment practices could affect the levels of fishery interaction with sea turtles (i.e., incidental catch or take rate)—bait type and color, hook size and shape, and day or night setting. The depth of set appears to be a far more important factor. Analysis of the SPC observer data suggests that in the tropical western Pacific setting longline gear shallow increases the rate of sea turtle takes by about 10 times compared to deep setting (OFP, 2001). Shallow sets are defined as longline gear configurations where <10 hooks are set between floats. Based on the long-term observer program of the Micronesian Maritime Authority, shallow night longline sets in the Exclusive Economic Zone of the Federated States of Micronesia (FSM) are four times more likely to catch turtles than deep longline sets, and hawksbill turtles are all caught on shallow night

sets (Park, 2002). The OFP analysis also shows that when sea turtle takes occur on deepset
gear, they are almost always on the shallowest hooks (OFP, 2001).
This information suggests a “turtle layer” in the water column or critical depth range of hooks where most sea turtle encounters would be expected to occur in western tropical Pacific longline fisheries (OFP, 2001). Observer data from the Hawaii longline fishery also
suggest the concept of a turtle layer in the sub-tropical North Pacific, where interactions on shallow-set longline gear are an order of magnitude higher than interactions on deep-set
gear (NMFS, 2001a). Figure 3 depicts the hypothesized turtle layer in relation to shallowset
and deep-set longline gear configurations.
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Figure 3. Comparison of deep-set and shallow-set pelagic longline gear in relationship to the proposed “sea turtle layer.”
Longline fishing depth varies significantly among the fleets profiled in the present study. The depth at which longline gear fishes is known to be influenced by the set configuration,
primarily the length of mainline between floats (a “basket”) and the sagging rate (Boggs, 1992). Fishing depth will also be influenced by a variety of environmental factors, particularly wind and currents (Boggs, 1992). The number of hooks between floats has been found to be a useful proxy for the targeted fishing depth of longline gear (Hampton et al., 1998).
Of the longline fisheries considered in the present study, Japan and Hawaii tuna fleets set
gear the deepest (40-400 m depth range fished), whereas the mixed-species fisheries of
most other nations set gear at shallower depths (35-250 m). Longline fisheries targeting swordfish, shark and mahimahi in the Pacific and Atlantic make even shallower sets (5-70
m depth range fished).
It has often been assumed that the distant-water Taiwan frozen tuna longline fleet deploys
gear in the same way as Japan’s distant-water frozen tuna longline fishery. Several sources
of information indicate that the Taiwan distant-water longline fishery sets gear in a manner
similar to what was defined as a “mixed set” in the Hawaii longline fishery from 1994-1999.
According to a report at the First International Fishermen’s Forum (Huang, p. 23 in Baird 2001), Taiwan’s distant-water tuna longline fleet typically sets 8-11 branch lines or hooks
between floats and soaks the gear during daylight hours (as opposed to Taiwan’s offshore
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longline fleet that sets 4-5 hooks between floats and soaks gear at night). Williams (2003: Figure 3, p. 5) reports that the distant-water Taiwanese longline fleet targeting albacore in the sub-tropical South Pacific (10-30° S) generally uses 9-12 hooks between floats and soaks gear during daylight hours.

From 1994-1999, all Hawaii longline sets with 10 or more branch lines between floats were characterized as “deep sets.” A drawing of an atypical (“mixed”) Hawaii tuna set configuration with 11 hooks between floats in WPFRMC (2004a: 13) shows that 8 of the hooks hypothetically would remain shallower than 100 m. This configuration does not necessarily result in a deep hook placement, especially if no slack is maintained while setting the mainline and it is characterized as a mixed set in the Hawaii longline fishery. Observed sea turtle takes for mixed sets were combined with observed sea turtle takes for swordfish sets for the purpose of distinguishing shallow sets from deep sets in NMFS’ definitions (NMFS, 2001a) that have been used in biological opinions and regulations applied to the Hawaii longline fishery. The mixed set gear configuration in the Hawaii longline fishery is similar to that of the distant-water Taiwanese frozen tuna longline fishery. Using NMFS’s criteria for combining mixed and swordfish gear configurations into a “shallow set” category for purposes of estimating incidental catch rates of sea turtles, the Taiwan distant-water freezer longline fishery should also be considered shallow set. With a minimum of 53 million hooks being set annually by the distant-water Taiwan freezer longline fleet in the central and western Pacific (Lawson, 2003: 53) and another 24 million hooks being set in different shallow configurations by other (principally Taiwan and China) longline fleets, (OFP, 2001: 19), a conservative estimate of the total shallow-set longline fishing effort by non-U.S. fleets in the central and western Pacific would be 77 million hooks per year. Under new regulations that allow up to 2,120 sets per year (WPRFMC, 2004a), a maximum of two million shallow-set hooks might be set per year in the model Hawaii swordfish fishery. Thus, the model fishery could account for about 2.5 percent of the total annual shallow-set longline fishing effort in the central and western Pacific.

5.2 Finfish Waste

Apex fish species make up the majority of the targeted fish and bycatch of pelagic longline fisheries. Data on the responses of oceanic gyre food webs to fishing are generally limited, so the food web impacts at lower trophic levels are not documented. Seki and Polovina (2001) used a dynamic ecosystem model to investigate possible impacts. They found no evidence that the removal of any single high trophic level species significantly altered the food web. The lack of a keystone species appears to be due to a high degree of diet overlap among the high trophic level species. Fisheries in oceanic gyres alter the food web by reducing the biomass at the top of the food web. When this reduction becomes substantial, it may result in some increase in biomass at mid-trophic levels (Seki and Polovina, 2001: 964).

Most longline fisheries are multi-species; i.e., they rely on the harvest of several ecologically related pelagic fish species for fishing income (Hoey and Moore, 1999). Discard of unwanted dead or live fish varies among longline fisheries due to several factors including the spatial and temporal variations in species distributions, fishing methods, skipper experience and preference, shipboard refrigerated storage capacity, marketing practices at unloading ports, differences in operating and marketing costs, and regulations (Anon. 20030a).

The present study focuses on wasted finfish, or “true bycatch;” i.e., fish discarded dead or mortally injured after incidental capture by pelagic longline fisheries. The delayed mortality of fish that are alive when discarded represents a large source of uncertainty in estimating true bycatch. Delayed mortality is related not only to the stress of capture and handling on deck but also to a suite of environmental stressors (e.g., exposure of deep-dwelling species to pressure changes, increased temperature and light) and biological stressors (size- and species-related sensitivities to stress) (Davis, 2002).

Pelagic longlining is selective in which ocean strata are targeted (i.e., the depth range in which the most hooks are set) but it is unselective in which pelagic fish are hooked within those strata, although they are predominantly high-level predator species. Thus, the species composition of what is captured changes with depth of set and possibly other factors, such as whether gear soaks during the day or night. Figure 4 shows typical time periods of setting, soaking and hauling for deep-set and shallow-set longline gear configurations.

The frequency of target species discards (as a percentage of each species’ observed catch) in western and central Pacific longline fisheries has been summarized by Sharples et al. (2000) from observer reports in SPC data holdings. For tuna and billfish species, the proportion discarded by different fleets (vessel nation) and reasons for discards are summarized in the same report. The main reason for discard of tuna and marlin is shark or whale damage. Over half of all marlin were alive when retrieved to the vessel compared to only about onethird of swordfish, sailfish, and shortbill spearfish.

Figure 4. Conceptual diagram contrasting deep-set and shallow-set pelagic longline fishing methods: time of setting, soaking and hauling.

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Unwanted finfish may be discarded dead or alive after retrieval onto the vessel or the fish may be cut or jerked free from the line by the crew before the fish are landed on the vessel. Discarding can occur for several reasons: 1) undesirable, poor food quality or low value species (e.g., oilfish, snake mackerel, lancetfish); 2) limited cold storage space on vessel (e.g., distant-water longline vessels making long trips far from offloading ports); 3) damaged fish (e.g., mauled by sharks or marine mammals); 4) difficult to land or process (e.g., large sharks, marlin) (Bailey et al., 1996); or 5) too small (e.g., swordfish) (Sharples et al., 2000).

6. BYCATCH PER UNIT OF EFFORT (BPUE) IN SELECTED LONGLINE FISHERIES

Fisheries bycatch can be expressed quantitatively as a function of the catch of primary target species. The specific index proposed by Hall (1996) is a ratio of numbers or weights of incidentally caught animals per unit of fishing effort (BPUE) or per unit of target fish catch (B/C). These indices standardize bycatch rates and allow comparison of different fisheries that harvest and market the same products.

The problem in calculating BPUE for the world’s pelagic longline fisheries is the paucity of data, especially concerning the proportions of sea turtles and finfish captured and released alive and the post-release survival of injured finfish and sea turtles. The unreliability of logbook data to provide indications of incidental catch levels (except for the more valuable billfish species) has led to recommendations for improvement of longline observer programs to expand coverage; to document species, quantities, sizes and life status of animals when discarded, spatial and temporal variations in discards; and to indicate reasons for discarding (Bailey et al., 1996; Lawson, 1997; WPRFMC, 2003).

Most researchers and managers have identified shipboard observer data as the most reliable means for obtaining indications of bycatch in pelagic longline fisheries (Bailey, et al., 1996;

Cheng, 2003; WPRFMC, 2003). NMFS (2003) has also concluded that at-sea observation typically provides the best way to obtain reliable and accurate bycatch estimates.

Interactions with sea turtles in central and western Pacific longline fisheries are relatively rare (Williams, 1996), so there is great uncertainty in estimating fisheries-wide sea turtle take and mortality from a low level of observer coverage (OFP, 2001). During the first 6 years of the Hawaii longline observer program (1994-1999), observers were placed on 3-5 percent of fishing trips by the Hawaii fleet. As a result of court orders and subsequent regulations, the level of coverage was increased to a minimum of 20 percent in later years. However, interactions with turtles are now so infrequent that take estimates are actually less precise than before—despite higher observer coverage (Wetherall, 2003). This occurred as a result of regulations in effect from mid-2001 to April 1, 2004 that prohibited Hawaii longline vessels from making shallow sets, the primary source of turtle interactions.

Finfish bycatch in this study is limited to waste; i.e., animals released dead or dying after incidental capture (Hall, 1996). To distinguish this negative effect (i.e., waste) from the

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positive effect of releasing finfish alive after incidental capture, observer programs need to record the life status of finfish releases. NMFS now instructs Hawaii longline observers to distinguish bycatch based on live or dead condition.

"…'Alive' indicates that the animal swam away when released from the gear or were thrown back overboard. Fish returned alive must be recorded as live in the caught condition column…'Dead' indicates the animal did not swim away after being returned. There may be no visible muscular activity and the animal may be stiff or limp. Inactive fish should be marked as returned dead." (Pacific Islands Regional Office, 2003: 45)

The SPC requires observers to record the life status of the individual catch from longline vessels at the time of retrieval in one of the following categories (Williams, 1997).

- Alive
- Alive healthy
- Alive—injured or distressed (with a good chance of surviving)
- Alive but dying
- Dead
- Condition unknown

Observers report that it can be difficult to decide if injured animals are dying (Sharples et al., 2000).

In the following sections (6.1, 6.2), BPUE is estimated for sea turtles (i.e., lethal and nonlethal incidental takes) and for wasted fish (i.e., true bycatch) in selected longline fisheries for which some observer data are available. Calculation of BPUE is based on a wide variation of observer coverage of these fisheries. For some fleets, BPUE is calculated from a very small number of observations.

For sea turtles, BPUE is expressed as numbers of animals (both dead and alive) incidentally captured by 10,000 hooks of longline fishing effort. Numbers of fish, instead of weight, are generally preferred to compare catch levels since the average weights of some pelagic species can vary markedly (Bailey, et al., 1996). In the present study, however, it is more useful to express BPUE of finfish waste in terms of weight so that comparisons can be made in the context of global fish trade.

6.1 C/B and B/C Ratios for Sea Turtles in Selected Longline Fisheries

This section contains a series of tables (Tables 7-11) that make preliminary estimates of sea turtle BPUE based on observer data (some of it very limited) for selected longline fisheries in the central and western Pacific, eastern Pacific, Indian Ocean and South Atlantic. Sea turtle BPUE—number of animals taken per 10,000 hooks—is compared to target fish CPUE (weight of target species per 10,000 hooks) for the same fisheries. C/B ratios are calculated by dividing CPUE by BPUE (canceling out the PUE term) to express the weight (mt) of target catch associated with the take of one sea turtle. B/C ratios are the inverse,

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calculated as the number of sea turtle takes per weight (mt) of target catch. These indices are derived by performing the calculations shown in Table 7.

For the purposes of this analysis, all takes of all sea turtle species are treated equally. Lumping is necessary because of the paucity of data and inadequate species identification in most observed longline fisheries. The impact of a turtle take actually varies considerably depending on the species taken, its condition after capture, its life stage and the status of its population. For example, a take of an adult from a severely depleted population, such as eastern Pacific leatherbacks, would be more significant than the take of a juvenile from a healthier population, such as Atlantic leatherbacks. However, no distinction or weighting based on turtle species, life stage or population status is made in the present study.

Table 7. Derivation of BPUE, CPUE, B/C and C/B ratios in Tables 8-11.

Column (1)

Area and
Longline fishery
Column (2)
CPUE
Target fish
(mt/10,000 hooks)
Column (3)
BPUE
Sea turtle
(takes/10,000
hooks)
Column (4)
B/C Ratio
Sea turtle (takes/
mt target fish)
Column (5)
C/B Ratio
Target fish (mt/
sea turtle take)
Longline fishing
grounds and flag of
Fishery A
Average catch
of targeted fish
species per 10,000
hooks. Footnotes
give sources
of data for this
calculation.[1]
Number of sea
turtles (combined
species)
incidentallycaptured
per
10,000 hooks.
Footnotes give
sources of data for
this calculation.[2]
Column 3
calculation
divided by column
2 calculation.
Results may differ
for fisheries with
similar column 3
incidental catch
rates because of
the sensitivity to
column 2 target
species catch rates.
Column 2
calculation divided
by column 3
calculation. Results
may differ for
fisheries with

similar column 3 incidental catch rates because of the sensitivity to column 2 target species catch rates.				
Longline fishing grounds and flag of Fishery B	As above	As above	As above	As above
Longline fishing grounds and flag of Fishery C	As above	As above	As above	As above

[1, 2]Footnotes give sources of data for this calculation

Table 8. Sea turtle BPUE, target fish CPUE, B/C and C/B in selected central and western Pacific deep-set pelagic longline fisheries.

Area and Longline fishery		**CPUE Target fish (mt/10,000 hooks)**	**BPUE Sea turtle (takes/10,000 hooks)**	**B/C Ratio Sea turtle (takes/mt target catch)**	**C/B Ratio Target fish (mt/sea turtle take)**
Sub-tropical South Pacific—American Samoa and Samoa alia albacore longline fisheries	Tuna	5.4[1]	None caught in 54,000 hooks[2]	0	100+
Western Tropical Pacific—Japan BE, YF tuna longline fishery	Tuna	4.1[3]	0.0692[4]	0.02	59
Sub-tropical central North Pacific—Hawaii BE, YF tuna longline fishery	Tuna	3.0[5]	0.051[6]	0.017	59

[1] Calculated from WPRFMC (2004b: average CPUE and fish weight estimates for albacore, bigeye and yellowfin tuna for 2000-2002, Tables 7a, 7b, 8).

[2] Calculated from OFP unpublished observer data for Samoa plus PacMar Inc., unpubl. research for American Samoa, Oct. 2003-April 2004).

[3] Calculated from Miyabe et al. (2003: p. 8, Table 2, average of 1998-2001).

[4] Calculated from OFP (2001).

[5] Calculated from WPRFMC (2004b: average CPUE and fish weight estimates for albacore, bigeye and yellowfin tuna, 1994-2002, p. 3-48, 3-49).

[6] Sea turtle take/tuna set from NMFS (2001a: Table IV-13) standardized to 10,000 hooks based on 1,900 hooks/tuna set during 1994-1999 period

(Ito and Machado, 2001: Tables 3, 4).

Table 9. Sea turtle BPUE, target fish CPUE, B/C and C/B in selected central and western Pacific shallow-set pelagic longline fisheries.

Area and Longline fishery		CPUE Target fish (mt/10,000 hooks)	BPUE Sea turtle (takes/ 10,000 hooks)	B/C Ratio Sea turtle (takes/mt target catch)	C/B Ratio Target fish (mt/sea turtle take)
Western Tropical Pacific—Taiwan BE, YF tuna longline fishery	Tuna	3.3[1]	0.6129[2]	0.19	5.4
WTP—People's Republic of China BE, YF tuna longline fishery	Tuna	2.4[3]	0.6129[2]	0.26	3.9
Eastern Australia swordfish fishery	Swordfish	4.8[4]	0.24[5]	0.05	20
Sub-tropical and temperate central North Pacific—Hawaii swordfish longline fishery (March 3, 1994 to June 30, 2001)	Swordfish	10.5[6]	1.7[7]	0.16	6.2

[1] Calculated from catch/effort statistics of Taiwan offshore longline fleet summarized by SPC unpubl. data.
[2] Calculated from OFP (2001).
[3] Calculated from Liuxiong (2002: Table 1, 3, average of 2000-2001).
[4] Calculated from Bromhead and Findlay (2003: Table 1, average of 1999-2002) by adjusting processed weight to whole weight (PW/0.89 = WW).
[5] Robins et al., (2002).
[6] Calculated from WPRFMC (2004b: average swordfish CPUE and average fish weight estimates 1994-1999, p. 3-50 and Table 6).
[7] Calculated as follows: average take of leatherback, loggerhead, olive ridley and green turtles per shallow swordfish-style set west of 150°W. (1994 through mid-2002) = 0.14/set (Caretta, 2003) divided by 820 hooks/set average (Ito and Machado, 2001) x 10,000 hooks.

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Table 10. Sea turtle BPUE, target fish CPUE, B/C and C/B in selected eastern Pacific shallow-set pelagic longline fisheries.

Area and Longline fishery	CPUE Target fish (mt/ 10,000 hooks)	BPUE Sea turtle (takes/10,000 hooks)	B/C Ratio Sea turtle (takes/mt

				target catch)	**C/B Ratio Target fish (mt/sea turtle take)**
Tropical eastern Pacific	Costa Rica offshore	Mahimahi 4.5[1]	66.7[2]	14.8	0.07
Tropical eastern Pacific	Costa Rica near nesting beaches	Mahimahi 4.5[1]	194[3]	43.1	0.02
Temperate eastern Pacific	California	Swordfish 12.9[4]	1.8[5]	0.14	7.2

[1] Calculated from the number of mahimahi caught per 1000 hooks (Arauz, 2001), assuming an average fish size based on Hawaii fresh mahimahi imports from Costa Rica (7.25 kg).
[2] Average incidental take of olive ridley and green turtles by Costa Rica artisanal longline fishery calculated from Arauz et al., (1999).
[3] Average incidental take of olive ridley and green turtles by Costa Rica industrial longline fishery calculated from Arauz (2001).
[4] Swordfish catch rates calculated from western Pacific longline logbook summary (all vessels California and high seas) for calendar years 2000-2002 (www.nmfs.hawaii.edu/fmpi/hilong/summary). Assumes average size (158 lb/fish) similar to swordfish landed by Hawaii longline fishery 2000-2001 (WPRFMC, 2004b: Table 6).
[5] Calculated as follows: average take of leatherback, loggerhead and olive ridley turtles per shallow swordfish-style set east of 150° W. (1994 through mid-2002) = 0.15/set (Caretta, 2003) divided by 820 hooks/set average (Ito and Machado, 2001) x 10,000 hooks.

Table 11. Sea turtle BPUE, target fish CPUE, B/C and C/B in selected south Atlantic shallow-set pelagic longline fisheries.

Area and Longline fishery		**CPUE Target fish (mt/10,000 hooks)**	**BPUE Sea turtle (takes/10,000 hooks)**	**B/C Ratio Sea turtle (takes/mt target catch)**	**C/B Ratio Target fish (mt/loggerhead take)**
South Atlantic Brazil—offshore	Swordfish	3.76[1]	18[2]	4.8	0.21
South Atlantic Brazil—near nesting beaches	Swordfish	3.76[1]	116[3]	30.9	0.03
South Atlantic South Africa	Swordfish	3.76[4]	5.95[5]	1.58	0.6

[1] Calculated from Anon. (2000).
[2] Average incidental take of mostly loggerhead turtles in the high seas off Brazil and Uruguay (Achaval et al., (2000).
[3] Average incidental take of loggerhead turtles in portions of Brazil's EEZ thought to be migratory corridors to or from nesting beaches (Barata et al., 1998).
[4] Assumes that average swordfish catch rates off South Africa are similar to those off Brazil.
[5] Hawksbill and loggerhead average incidental take by Taiwan distant-water longline fishery in temperate South Atlantic high seas (Cheng, 2003).

6.2 C/B and B/C Ratios for Finfish in Selected Longline Fisheries

A species-by-species accounting of finfish waste in pelagic longline fisheries is beyond the scope of the present study. Instead, four species of longline incidental finfish catch were selected to represent a spectrum of fates: discarded (longnose lancetfish), discarded after finning (blue shark), retained after finning (silky shark) and retained (shortbill spearfish).

- Blue shark (*Prionace glauca*) is a major component of the incidental finfish catch by both deep-set and shallow-set longline fleets. In non-U.S. fisheries, only the fins of this species are retained because the meat is inedible. Under the Shark Finning Prohibition Act, retention of fins without a corresponding amount of carcasses is illegal for U.S. fisheries.
- Silky shark (*Carcharinus falciformis*) is a major component of shallow-set longline fisheries in some areas. Taiwanese and Chinese fishing crews remove the fins but frequently retain the trunks of this species for processing.
- Longnose lancetfish (*Alepisaurus ferox*) is a major component of longline incidental finfish catch. Except for small quantities occasionally retained for crew use, most fish are discarded.
- Shortbill spearfish (*Tetrapturus angustirostris*) is a minor component of longline incidental finfish catch but the level of discard is strongly influenced by fishing trip length in relation to species' shelf life, marketing opportunities and practices at ports of landing. In the Hawaii tuna longline fishery, for example, spearfish caught during the first few days of a trip may be discarded because of the short shelf life of this species. But spearfish are retained when caught later in a trip (Gilman et al., 2003: 19).

Fish that are discarded alive and likely to survive are not wasted and, therefore, are not considered a part of true bycatch. This section contains a series of tables (Tables 12-20) that make preliminary estimates of finfish waste BPUE based on observer data (some of it very limited) for selected longline fisheries in the central and western Pacific and eastern Pacific.

Finfish waste BPUE—weight of animals taken per 10,000 hooks—is compared to target fish CPUE (weight of target species per 10,000 hooks) for the same fisheries. B/C ratios are calculated by dividing BPUE by CPUE and expressed as weight (mt) of finfish waste per mt of target catch. The C/B ratio is the weight (mt) of target catch to generate one mt of finfish waste. These indices are derived by performing the calculations shown in Table 12.

Table 12. Derivation of BPUE, CPUE, B/C and C/B ratios in Tables 13-20.

Column (1) Area and Longline fishery	**Column (2) CPUE Target fish (mt)/10,000 hooks**	**Column (3) BPUE Finfish waste (mt)/10,000 hooks**

Column (4)
B/C Ratio Finfish waste (mt)/target fish (mt)
Column (5)
C/B Ratio Target fish (mt)/finfish waste (mt)
Longline fishing grounds and flag of Fishery A
Average catch of targeted fish species per 10,000 hooks. Footnotes give sources of data for this calculation.[1]
Number of fish discarded dead or dying x average species wt. (mt) per 10,000 hooks. Footnotes give sources of data for this calculation.[2]
Column 3 calculation divided by column 2 calculation. Results may differ for fisheries with similar column 3 incidental catch rates because of the sensitivity to column 2 target species catch rates.
Column 2 calculation divided by column 3 calculation. Results may differ for fisheries with similar column 3 incidental catch rates because of the sensitivity to column 2 target species catch rates.
Longline fishing grounds and flag of Fishery B
As above As above As above As above
Longline fishing grounds and flag of Fishery C

As above As above As above As above

[1, 2] Footnotes give sources of data for these calculations.

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Table 13. Blue shark BPUE, target fish CPUE, B/C and C/B in selected central and western
Pacific deep-set pelagic longline fisheries.

Area and Longline fishery	CPUE Target fish (mt)/10,000 hooks	BPUE Blue shark bycatch (mt)/ 10,000 hooks)	B/C Ratio Blue shark bycatch (mt)/ target fish (mt)	C/B Ratio Target fish (mt)/ blue shark bycatch (mt)
Western Tropical Pacific—Japan BE, YF tuna longline fishery	4.1[1]	0.04[2]	0.01	103
Sub-tropical central North Pacific—Hawaii BE, YF tuna longline fishery	3.0[3]	0.028[4]	0.01	107

[1] Calculated from Miyabe et al., (2003: p. 8, Table 2, average of 1998-2001).

[2] Calculated as follows: average CPUE of blue shark observed discarded dead, injured, or unknown condition in western tropical Pacific (10°N–10°S) deep-set longline fisheries = 0.217/1000 hooks (summary of unpubl. SPC observer data, P. Williams, pers. comm.
to P. Bartram, April 26, 2004) = 2.17/10,000 hooks x 40 kg average size of blue shark between 20° N and 20° S latitudes in Pacific Ocean (Stevens, 1996).

[3] Calculated from WPRFMC (2004b: average CPUE and fish weight estimates for albacore, bigeye and yellowfin tuna, 1994-2002, p. 3-48, 3-49).

[4] Calculated as follows: Hawaii deep-set longline catch disposition for blue shark summarized for WPRFMC by NMFS PIFSC, May 12,
2004. Primary source is observer data gathered by NMFS PIRO observers assigned to Hawaii longline fleet, July 1, 2001-August 29, 2003
(after U.S. Shark Finning Prohibition Act went into force). Animals released dead, finned/dead or unknown are considered to be finfish waste
= 1.77/10,000 hooks x 40 kg average size of blue shark between 20 N and 20 S latitudes in Pacific Ocean (Stevens, 1996).

Table 14. Blue shark BPUE, target fish CPUE, B/C and C/B in selected western and eastern Pacific shallow-set pelagic longline fisheries.

Area and Longline fishery	CPUE Target fish (mt)/10,000 hooks	BPUE Blue shark bycatch (mt)/ 10,000 hooks)	B/C Ratio Blue shark bycatch (mt)/ target fish (mt)	C/B Ratio Target fish (mt)/blue shark bycatch (mt)
Western Tropical Pacific—Taiwan BE, YF tuna longline fishery				
Tuna				

		3.3[1]	0.24[2]	0.07	13.8
WTP—People's Republic of China BE, YF tuna longline fishery	Tuna	2.4[3]	0.24[2]	0.1	10
Sub-tropical and temperate central North Pacific—Hawaii swordfish longline fishery (March 3, 1994 to June 30, 2001)	Swordfish	10.5[4]	1.6[5]	0.15	6.6
Tropical eastern Pacific Costa Rica	Mahimahi	4.5[6]	0.12[7]	0.03	37.5

[1] Calculated from catch/effort statistics of Taiwan offshore longline fleet summarized by SPC.
[2] Calculated as follows. Average CPUE of blue shark observed discarded dead, injured, or unknown condition in western tropical Pacific (10°N–10°S) shallow-set longline fisheries, including a shark-targeted fishery = 1.34/1000 hooks (summary of unpubl. SPC observer data, P. Williams, pers. comm. to P. Bartram, April 26, 2004) = 13.4/10,000 hooks x 40 kg average size of blue shark between 20° N and 20° S latitudes in Pacific Ocean (Stevens, 1996).
[3] Calculated from Liuxiong (2002: Table 1, 3, average of 2000-2001).
[4] Calculated from WPRFMC (2004b: average swordfish CPUE and average fish weight estimates 1994-1999, p. 3-50 and Table 6).
[5] Calculated as follows. Hawaii shallow-set longline catch disposition for blue shark summarized for WPRFMC by NMFS PIFSC, May 12, 2004. Primary source is observer data gathered by NMFS PIRO observers assigned to Hawaii longline fleet, March 3. 1994 – June 30, 2001 (before U.S. Shark Finning Prohibition Act went into force). Animals released dead, finned/dead and unknown are considered to be finfish waste = 88.4 /10,000 hooks x 40 kg average size of blue shark between 20° N and 20° S latitudes in Pacific Ocean (Stevens, 1996).
[6] Calculated from the number of mahimahi caught per 1000 hooks (Arauz 2000, Table 2), assuming an average fish size based on Hawaii fresh mahimahi imports from Costa Rica (7.25 kg).
[7] Calculated as follows. Average CPUE of blue shark in Costa Rica domestic artisanal longline fishery = 7.38/10,000 hooks (Arauz, 2000, Table 7) x 93% of blue shark discarded after finning (Arauz, 2000, Table 4) x 40 kg average size of blue shark between 20° N and 20° S latitudes in Pacific Ocean (Stevens, 1996).

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Table 15. Silky shark BPUE, target fish CPUE, B/C and C/B in selected central and western Pacific deep-set pelagic longline fisheries.

Area and Longline fishery		**CPUE Target fish (mt)/10,000 hooks**	**BPUE Silky shark bycatch (mt)/10,000 hooks**	**B/C Ratio Silky shark bycatch (mt)/Target fish (mt)**	**C/B Ratio Target fish (mt)/ silky shark bycatch (mt)**
Western Tropical Pacific—Japan BE, YF tuna longline fishery	Tuna	4.1[1]	0.015[2]	0.004	273
Sub-tropical central North Pacific—Hawaii BE, YF tuna longline fishery					

	Tuna	3.0[3]	0.005[4]	0.002	600

[1] Calculated from Miyabe et al. (2003: p. 8, Table 2, average of 1998-2001).
[2] Calculated as follows. Average CPUE of silky shark observed discarded dead, injured, or unknown condition in western tropical Pacific (10°N–10°S) deep set longline fisheries = 0.11/1000 hooks (summary of unpubl. SPC observer data, P. Williams, pers. comm.
with P. Bartram, April 26, 2004) = 1.1/10,000 hooks x 30 kg median size of silky shark in Pacific (Oshitani et al., 2003: Fig. 3).
[3] Calculated from WPRFMC (2004b: average CPUE and fish weight estimates for albacore, bigeye and yellowfin tuna, 1994-2002, p. 3-48, 3-49).
[4] Calculated as follows. Hawaii deep-set longline catch disposition for silky shark summarized for WPRFMC by NMFS PIFSC, May 12, 2004. Primary source is observer data gathered by NMFS PIRO observers assigned to Hawaii longline fleet, July 1, 2001 – August
29, 2003 (after U.S. Shark Finning Prohibition Act went into force). Animals released dead, finned/dead and unknown are considered
to be finfish waste = 0.345/10,000 hooks x 30 kg median size of silky shark in Pacific (Oshitani et al., 2003: Fig. 3).

Table 16. Silky shark BPUE, target fish CPUE, B/C and C/B in selected western and eastern Pacific shallow-set pelagic longline fisheries.

Area and Longline fishery	**Target fish**	**CPUE Target fish (mt)/10,000 hooks**	**BPUE Silky shark bycatch (mt)/ 10,000 hooks**	**B/C Ratio Silky shark bycatch (mt)/ Target fish (mt)**	**C/B Ratio Target fish (mt)/silky shark bycatch (mt)**
Western Tropical Pacific—Taiwan BE, YF tuna longline fishery	Tuna	3.3[1]	0.063[2]	0.02	52
WTP—People's Republic of China BE, YF tuna longline fishery	Tuna	2.4[3]	0.063[2]	0.03	38
Sub-tropical and temperate central North Pacific—Hawaii swordfish longline fishery (March 3, 1994 to June 30, 2001)	Swordfish	10.5[4]	0.001[5]	0.0001	10500
Tropical eastern Pacific—Costa Rica	Mahimahi	4.5[6]	0.038[7]	0.01	118

[1] Calculated from catch/effort statistics of Taiwan offshore longline fleet summarized by SPC.
[2] Calculated as follows. Average CPUE of silky shark observed discarded dead, injured, or unknown condition in western tropical Pacific (10°N–10°S) shallow set longline fisheries, including a shark-targeted fishery = 0.465/1000 hooks (summary of unpubl. SPC observer data, P. Williams, pers. comm. with P. Bartram, April 26, 2004) = 4.65/10,000 hooks x 30 kg median size of silky shark in Pacific (Oshitani et al., 2003: Fig. 3).
[3] Calculated from Liuxiong (2002: Table 1, 3, average of 2000-2001).

[4] Calculated from WPRFMC (2004b: average swordfish CPUE and average fish weight estimates 1994-1999, p. 3-50 and Table 6).
[5] Calculated as follows. Hawaii shallow-set longline catch disposition for silky shark summarized for WPRFMC by NMFS PIFSC, May 12, 2004. Primary source is observer data gathered by NMFS PIRO observers assigned to Hawaii longline fleet, March 3, 1994–June 30, 2001 (before U.S. Shark Finning Prohibition Act went into force). Animals released dead, finned/dead and unknown are considered to be finfish waste = 0.065/10,000 hooks x 30 kg median size of silky shark in Pacific (Oshitani et al., 2003: Fig. 3).
[6] Calculated from the number of mahimahi caught per 1000 hooks (Arauz, 2000, Table 2), assuming an average fish size based on Hawaii fresh mahimahi imports from Costa Rica (7.25 kg).
[7] Calculated as follows. 46.84 silky shark/10,000 (Arauz, 2000: Table 7) x 6% discarded after finning (Arauz, 2000: Table 4) x 30 kg median size of silky shark in Pacific (Oshitani et al., 2003: Fig. 3).

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Table 17. Longnose lancetfish BPUE, target fish CPUE, B/C and C/B in selected central and western Pacific deep-set pelagic longline fisheries.

Area and Longline fishery	**Target fish**	**CPUE (mt/10,000 hooks)**	**BPUE Longnose lancetfish bycatch (mt)/ 10,000 hooks)**	**C/B Ratio Longnose lancetfish bycatch (mt)/ target fish (mt)**	**B/C Ratio Target fish (mt)/longnose lancetfish bycatch (mt)**
Western Tropical Pacific—Japan BE, YF tuna longline fishery	Tuna	4.1[1]	0.001[2]	0.0002	4100
Sub-tropical central North Pacific—Hawaii BE, YF tuna longline fishery	Tuna	3.0[3]	0.013[4]	0.004	231

[1] Calculated from Miyabe et al. (2003: p. 8, Table 2, average of 1998-2001).
[2] Calculated as follows. Average CPUE of longnose lancetfish observed discarded dead, injured, or unknown condition
in western tropical Pacific (10°N–10°S) deep set longline fisheries = 0.142/1000 hooks (summary of unpubl. SPC observer data, P. Williams, pers. comm. to P. Bartram, April 26, 2004) = 1.4/10,000 hooks x 2 kg median weight from weight-on-length relationship in Uchiyama and Kazama (2003: Figure 20, p. 34).
[3] Calculated from WPRFMC (2004b: average CPUE and fish weight estimates for albacore, bigeye and yellowfin tuna, 1994-2002, p. 3-48, 3-49).
[4] Calculated as follows. Hawaii deep-set longline catch disposition for longnose lancetfish summarized for WPRFMC by NMFS PIFSC, May 12, 2004. Primary source is observer data gathered by NMFS PIRO observers assigned to Hawaii longline fleet, March 3, 1994–August 29, 2003. Animals released dead and unknown are considered to be finfish waste = 14.8 /10,000 hooks x 2 kg median weight from weight-on-length relationship in Uchiyama and Kazama (2003: Figure 20, p. 34).

Table 18. Longnose lancetfish BPUE, target fish CPUE, B/C and C/B in selected central and western Pacific shallow-set pelagic longline fisheries.

Area and Longline fishery	Target fish	CPUE (mt/10,000 hooks)	BPUE Longnose lancetfish bycatch (mt)/ 10,000 hooks)	C/B Ratio Longnose lancetfish bycatch (mt)/ target fish (mt)	B/C Ratio Target fish (mt)/longnose lancetfish bycatch (mt)
Western Tropical Pacific—Taiwan BE, YF tuna longline fishery	Tuna	3.3[1]	0.001[2]	0.0003	3300
WTP—People's Republic of China BE, YF tuna longline fishery	Tuna	2.4[3]	0.001[2]	0.0004	2400
Sub-tropical and temperate central North Pacific—Hawaii swordfish longline fishery (March 3, 1994 to June 30, 2001)	Swordfish	10.5[4]	0.01[5]	0.001	1050

[1] Calculated from catch/effort statistics of Taiwan offshore longline fleet summarized by SPC unpubl. data.

[2] Calculated as follows. Average CPUE of longnose lancetfish observed discarded dead, injured, or unknown condition in western tropical Pacific (10°N–10°S) shallow-set longline fisheries, including a shark-targeted fishery = 0.082/1000 hooks (summary of unpubl. SPC observer data, P. Williams, pers. comm. to P. Bartram, April 26, 2004) = 0.8/10,000 hooks x 2 kg median size in length-weight relationship of 200 (Uchiyama and Kazawa, 2003: Figure 20, p. 34).

[3] Calculated from Liuxiong (2002: Table 1, 3, average of 2000-2001).

[4] Calculated from WPRFMC (2004b: average swordfish CPUE and average fish weight estimates 1994-1999, p. 3-50 and Table 6).

[5] Calculated as follows. Hawaii shallow-set longline catch disposition for longnose lancetfish summarized for WPRFMC by NMFS PIFSC, May 12, 2004. Primary source is observer data gathered by NMFS PIRO observers assigned to Hawaii longline fleet, March 3. 1994–June 30, 2001. Animals released dead and unknown are considered to be finfish waste = 11.0/10,000 hooks x 2 kg median size in length-weight relationship of 200 (Uchiyama and Kazawa, 2003: Figure 20, p. 34).

Table 19. Shortbill spearfish BPUE, target fish CPUE, B/C and C/B in selected central and western Pacific deep-set pelagic longline fisheries.

Area and Longline fishery CPUE
Target fish
(mt)/10,000

hooks
BPUE Shortbill
spearfish
bycatch (mt)/
10,000 hooks
B/C Ratio
Shortbill spearfish
bycatch (mt)/
target fish (mt)
C/B Ratio
Target fish
(mt)/shortbill
spearfish
bycatch (mt)
Western Tropical Pacific—Japan
BE, YF tuna longline fishery
Tuna
4.1[1]
0.002[2] 0.001 2050
Sub-tropical central North
Pacific—Hawaii BE, YF tuna
longline fishery
Tuna
3.0[3]
0.002[4] 0.001 1500

[1] Calculated from Miyabe et al. (2003: p. 8, Table 2, average of 1998-2001).
[2] Calculated as follows. Average CPUE of shortbill spearfish observed discarded dead, injured, or unknown condition in
western tropical Pacific (10°N–10°S) deep-set longline fisheries = 0.028/1000 hooks (summary of unpubl. SPC observer
data, P. Williams, pers. comm. with P. Bartram, April 26, 2004) = 0.28/10,000 hooks x 14.5 kg average weight of shortbill spearfish caught 1994-2002 in Hawaii longline fishery (WPRFMC, 2004b: Table 6).
[3] Calculated from WPRFMC (2004b: average CPUE and fish weight estimates for albacore, bigeye and yellowfin tuna, 1994-2002, p. 3-48, 3-49).
[4] Calculated as follows. Hawaii deep-set longline catch disposition for shortbill spearfish summarized for WPRFMC by NMFS PIFSC, May 12, 2004. Primary source is observer data gathered by NMFS PIRO observers assigned to Hawaii
longline fleet, March 3, 1994–August 29, 2003. Animals released dead and unknown are considered to be finfish waste
= 0.34/10,000 hooks x 14.5 kg average weight of spearfish caught 1994-2002 in Hawaii longline fishery (WPRFMC, 2004b: Table 6).

Table 20. Shortbill spearfish BPUE, target fish CPUE, B/C and C/B in selected central and
western Pacific shallow-set pelagic longline fisheries.

Area and Longline fishery CPUE
Target fish
(mt)/10,000
hooks
BPUE Shortbill
spearfish
bycatch (mt)/
10,000 hooks
B/C Ratio
Shortbill
spearfish
bycatch (mt)/
target fish (mt)

C/B Ratio
Target fish
(mt)/shortbill
spearfish
bycatch (mt)
Western Tropical Pacific—Taiwan
BE, YF tuna longline fishery
Tuna
3.3[1]
0.001[2] 0.0003 3300
WTP—People's Republic of China
BE, YF tuna longline fishery
Tuna
2.4[3]
0.001[2] 0.0004 2400
Sub-tropical and temperate central
North Pacific—Hawaii swordfish
longline fishery (March 3, 1994 to
June 30, 2001)
Swordfish
10.5[4]
0.004[5] 0.0004 2625

[1] Calculated from catch/effort statistics of Taiwan offshore longline fleet summarized by SPC unpubl. data.
[2] Calculated as follows. Average CPUE of shortbill spearfish observed discarded dead, injured, or unknown condition in
western tropical Pacific (10°N–10°S) shallow-set longline fisheries, including a shark-targeted fishery = 0.019/1000 hooks
(summary of unpubl. SPC observer data, P. Williams, pers. comm. to P. Bartram, April 26, 2004) = 0.19/10,000 hooks x
14.3 kg average weight of shortbill spearfish caught 1994-1999 in Hawaii longline fishery (WPRFMC, 2004b: Table 6).
[3] Calculated from Liuxiong (2002: Table 1, 3, average of 2000-2001).
[4] Calculated from WPRFMC (2004b: average swordfish CPUE and average fish weight estimates 1994-1999, p. 3-50 and Table 6).
[5] Calculated as follows. Hawaii shallow-set longline catch disposition for shortbill spearfish summarized for WPRFMC by NMFS PIFSC, May 12, 2004. Primary source is observer data gathered by NMFS PIRO observers assigned to Hawaii longline fleet, March 3. 1994–June 30, 2001. Animals released dead and unknown are considered to be finfish waste = 0.54/10,000 hooks x 14.3 kg average weight of shortbill spearfish caught 1994-1999 in Hawaii longline fishery
(WPRFMC, 2004b: Table 6).
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Sea turtlebycatchtofishcatchratiosfordifferentiatingHawaiilongline- caught seafoodproducts

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a r t i c l e info Article history: Received21May2009 Accepted30May2009 Keywords: Bycatchtocatchratios Sea turtles Sustainable seafood Hawaiilonglinefisheries

a b s t r a c t Sea turtlescanbeincidentallycaughtinpelagiclonglinefishinggeartargetingtunaandswordfish. Bycatchtofishcatch(B/C)ratioscandifferentiateseafoodbasedonseaturtleimpacts.Thisstudy demonstratestheuseofB/Cratiosindexedtotheweightoffishcatch:(1)toreportonthesignificant progressinreducingseaturtlebycatchinHawaii'sswordfishlonglinesectorand(2)tocompareHawaii and otherPacificlonglinefisheriesbynumberofseaturtleinteractionsperweightofcatch.Hawaii's longlinetunafisherysetsthebenchmarkof1seaturtleinteractionper190,000kgoftunacaught.

1.Introduction

1.1.Purposeofstudy Incidental catchesofseaturtlesarerareinHawaiiandother central andwesternPacificpelagiclonglinefisheries [1]. Yet, protectionoftheseandothercharismaticmarinespecies,suchas seabirdsandmarinemammals,hasbecomeaveryimportant,if not dominantfactorinfisheriesmanagement [2]. Seaturtlesare protectedundertheUSEndangeredSpeciesAct.Unintentional fishery interactionswiththesethreatenedorendangeredspecies are oneexampleofecosystemimpactsthataffectthepublic perceptionofthesustainabilityofseafoodproducedbylongline fisheries. Consumersareoftenunawareoftheenvironmentalconse- quencestheyimplicitlyendorsewhenbuyingseafoodfrom differentsources.Asawarenessofenvironmentalissuesassociated with fishingandfisheryproductsgrows,consumerpreferences and marketdemandforparticularspeciesandsourcesofseafood can beinfluenced [3]. Asamatterofcorporateresponsibility marketersneedtoadoptsustainableseafoodpurchasingstandards that specifyobjectiveandmeasurablecriteriafordeterminingthe sustainabilityofdifferentsourcesofseafood.Tomoreeffectively supportresponsiblefisheries,practicalmeasurestoeasilydiffer- entiateseafoodharvestedsustainablyusinglow-impactmethods fromseafoodoflesssustainableoriginsareneeded. Existing scientificmeasuresoffisheryimpactsonprotected species arebasedontherateofinteractionspermeasureoffishing effort. Butthisisnotintuitivelytranslatedtoimpactsassociated with aweightofseafoodproduced.Differentmeasuresandnew communication toolsforreadilyconveyingsuchinformationare needed. Thepracticalquestionforthetunaandswordfishmarket is whichproductsourcecarrieswithittheleastamountof ''environmentalbaggage''byweightoftheseafood. The purposeofthisstudyistodemonstratehowBycatchto Catch (B/C)ratioscananswerthisquestion.B/Cratioswereused to establishabenchmark,tracktheprogressofHawaii'sswordfish longline sectorinreducingseaturtlebycatchandtocompare fishery productsfromHawaiiandotherPacificlonglinefisheries bythenumberofseaturtleinteractionsperweightofseafood. 1.2.Whyseaturtlesarecapturedincidentallyinlonglinefisheries Incidental catchofseaturtlesmayoccurwhenfeedinganimals opportunisticallyencounterbaitedlonglinehooksorwhenthey are accidentallyentangledwithlonglinegear.Theseinteractions take placeduringthepelagicperiodsofseaturtles'liveswhile migratingthroughtheopenoceanwheretheirdensityislow,and to andfrominshorefeedingorbreeding/nestinghabitatswhere theyaremorelikelytobeaggregatedatgreaterdensity. Sea turtlesrelyontheirvisualsensesinthesearchforfoodand need tosurfaceatregularintervalstobreathe.Somespeciesalso exhibitapreferencefordistinctoceanthermalregimes.These basic attributeshaveimplicationsforthelikelihoodofpotential interactionswithpelagiclonglinefishinggearandtheoutcomes of thoseinteractions [4]. The generaldesignofpelagiclonglinegearisrelativelysimple but itisnotasingleoruniformmethodoffishing.Thereare considerabledifferencesbetweenandwithinfishingfleets.A ARTICLEINPRESS Contents listsavailableat ScienceDirect journalhomepage: www.elsevier.com/locate/marpol MarinePolicy

doi:10.1016/j.marpol.2009.05.006 _ Correspondingauthor.Tel.:+18087352602;fax:+18087342315. E-mail address: pacmar@pacmarinc.com (J.JohnKaneko). Marine Policy 34 (2010) 145–149

ARTICLEINPRESS mainline isdeployedhorizontallyforupto40milesacrossthe ocean. Itissuspendedinthewatercolumnbetweenmultiplefloat lines andfloats.Branchinglinesendinginbaitedhooksdescend verticallyfromthemainlineatintervalsbetweenfloatsthatcause each arrayofhookstodeploythrougharangeofoceandepths. The depthofthehooksisdeterminedinlargepartbythelength and sinkingrateofthemainlinebetweenfloats,andthelengthof the floatlinesandbranchlines.Longlinefishingisdonein''sets'' which beginwithdeployingthegearandendwhenallthegear has beenretrieved. The rateofseaturtlebycatchdependsonhowlonglinegearis configured,whereandwhengearissetinrelationtothehabitat, distribution andabundanceofturtles,andbehaviorofturtle species. Seaturtlesareairbreathersandinhabittheupperlayers of theocean,especiallytheupper50m(''turtlelayer'').When longline gearissetrelativelyshallowinthewatercolumnto target swordfish,mosthooksaredeployedwithinthe''turtle layer'',wherethereisahigherlikelihoodofinteractionswithsea turtles. Whengearissetdeepertotargetbigeyetuna,themajority of hooksaredeployedbelowthe''turtlelayer'',sothatthereare fewerinteractionswithseaturtles [4]. 1.3.Seaturtlebycatch Incidental catchofseaturtlesinUSfisheriesisconsidereda type of''bycatch''.TheUSMagnuson-StevensFisheryConserva- tion andManagementAct(MSFCMA)guidesHawaiilongline fisheries management.UndertheMSFCMAdefinition,bycatchof sea turtlesincludesallanimalsreleasedafterinteractionwith fishing gearregardlessoftheirfate. Other definitionsofmarinebycatcharebasedonmortalityand waste.AccordingtoHall [2], bycatchislimitedtomarinespecies releasedafterincidentalcaptureeitherdeadorwithapoorchance of survival.ThepresentstudyutilizesHawaiilonglineseaturtle bycatchdatacollectedbytheNationalOceanicandAtmospheric Administration(NOAA)FisheriesServicefollowingtheMSFCMA definition. Seaturtlebycatchismeasuredin''takes''fromNOAA Fisheries' shipboardobserverrecordsthataredefinedasall interactionswithlonglinegear,regardlessofwhetheranimalsare dead, injured,oraliveandunharmedwhenreleased [5]. 1.4.Hawaiilonglinefisheries A tunalonglinefisherywasfirstestablishedinHawaiiin1917. This fleetremainedrelativelysmalluntilthelate1980s,when new USboatsenteredthefisheryfromtheUSPacificandAtlantic coasts andtheGulfofMexico.Contributingtothisfleetexpansion wasthediscoveryofcommercialconcentrationsofswordfish north ofHawaii.ThenewfisherydiversifiedtheHawaiilongline fleet intoadeep-setsectortargetingbigeyetunaandashallow-set sector targetingswordfish [6]. Concerns aboutunrestrainedfleetexpansionandpossibilityof future over-capacitycausedtheWesternPacificFisheryManage- ment CounciltorecommendalimitedentrysystemforNOAA Fisheries approvalandimplementation.Amoratoriumonnew vesselentrytoHawaiilonglinefisherieswasestablishedin1991 and thisevolvedintothepresentlimitedaccesspermitsystem [7]. The numberofpermittedvesselswascappedatamaximumof 164vessels,buttheHawaiilonglinefleethasnumbered141 vesselsorlesssincethelimitwasestablished [8]. BothsectorsofHawaiilonglinefisheryoperateundertheUS EndangeredSpeciesAct(ESA),aswellastheMSFCMA.TheESA requiresNOAAFisheriestosetmaximumlimitsforannualHawaii longline fisheryinteractionswithseaturtlesbecauseoftheir protectedstatus.Since1994,Hawaiilonglinevesselshavebeen requiredtocarryshipboardobserverswhenrequestedbyNOAA Fisheries tomonitorinteractionswithseaturtlesandother protectedspecies.Duringthefirst6yearsoftheHawaiilongline observerprogram(1994–1999),observersaccompanied3–5%of fishing tripsbytheHawaiifleet.Theseaturtleinteractions actuallyobservedduringthisperiodwererare,butstatistical expansionofthelimiteddatatotheentirefisherysuggestedthat severalhundredturtlesmightbeimpactedannually.Asaresult,a NOAAFisheries'BiologicalOpinionissuedin2001temporarily closed theswordfishsectoroftheHawaiilonglinefisheryand prohibitedtunalonglinetripssouthof15N.latitudetothe equatorduringthemonthsofAprilandMay [9]. 1.5.ManagementregimechangeintheHawaiilonglinefisheries As aresultofcourtordersandNOAAFisheries'Biological Opinionsandregulations,theHawaiiswordfishlonglinefisherywas re-openedin2004aftersignificantmanagementmeasureswere implementedtoreduceseaturtleinteractions [10]. Underthenew managementregime,swordfishdirectedefforthasbeencappedat 2120shallow-setlonglinesetsperyear.Vesseloperatorsmust declaretoNOAAinadvanceofeachtripwhetherswordfish (shallowsets)ortuna(deepsets)willbemade.Theymustalso submitshallow-setcertificatesforeachshallowsetmadeduringa swordfishtriptoNOAAwithin72hofeachlanding.Vesselsmaking shallowsetsnorthoftheequatorarerequiredtouseonlycircle hookssized18/0orlargerwitha101 offsetandonlymackerel-type bait (nosquid)thathavebeenshowntoreducetherateandseverity ofseaturtlehookingevents.AllHawaiilonglinevessels(tunaand swordfish)mustcarryanduseNOAAapprovedde-hookingdevices. The levelofobservercoveragewasincreasedtoaminimumof20% ofHawaiitunalonglinetrips(sincemid-2001)and100%ofHawaii swordfishlonglinetrips(sincemid-2004) [11]. Followingthe increasedshipboardobservercoverage,thelevelofseaturtle interactionsinbothsectorswasmoreaccuratelyquantifiedthan previously.TheHawaiiswordfishfisheryoperateswithareal-time annual hardcapof16leatherbackand17loggerheadinteractions.If eitherspeciescapisreached,regardlessoftheseverityofthe interaction(includingthelivereleaseofunharmedanimals)the fisheryisclosedimmediatelyfortheremainderoftheyear. 1.6.ReductionofseaturtlebycatchinHawaii'sswordfishlongline fishery The Hawaiilonglineswordfishfishingindustry,workingwith fisheries scientistsandmanagers,hasmadesignificantprogressin reducingincidentalinteractionswithseaturtles.Management measuresthatwereconditionsofre-openingtheswordfishsector in mid-2004haveresultedinasubstantialandwell-documented 89% reductioninbycatchperuniteffort(BPUE)from0.174 (1994–1999)downto0.019(2004–2006)incidentalcapturesofall sea turtlespeciesper1000hookssetintheHawaiiswordfish sector [12]. 2. Methodology Bycatchtocatch(B/C)ratiosareproposedasanindexfor representingandcomparingseaturtleimpactsinrelationtothe weightoftargetfishcatches.Dr.MartinHalloftheInter-American TropicalTunaCommissionfirstusedB/Cratiostocomparethe bycatchimpactsofdifferentpurseseinefishingmethodsin easternPacifictunafisheries [2]. B/C ratiosarederivedbydividingafishery'sCPUE(fishcatch weightperunitoffishingeffort)byitsBPUE(bycatchperunitof P.K.Bartrametal./MarinePolicy34(2010)145–149 146

fishing effort).CPUEisusuallyestimatedfromlogbookreportsof fish catchandeffort,whereasBPUE(numberofseaturtletakes per unitoffishingeffort)canonlybereliablyestimatedfrom shipboard observermonitoring(Table1). Detailednotesonthe sourcedata,assumptionsandcalculationsforeachofthefisheries comparedaregivenin Table1. Sea turtlebycatch,estimatedasnumberoffisheryinteractions, or ''takes'',rangefornon-lethalentanglementwithnoinjuryto hooking eventswithimmediateorpossibledelayedmortality.For this reason,thenumbersofseaturtletakesquantifiedinthis report arenotequivalenttomortalities. 3. Results B/C ratiosrepresentthemagnitudeofseaturtleinteractions associatedwithacommonweightoftargetfishcatch.B/Cratios are expressedinapictorialformatin Figs. 1and2. Theareasofthe circles areproportionaltothenumberofseaturtletakesper 190,000kgoftargetfish(tunaorswordfishcaught).Hawaii'stuna longline fishery,withthelowestB/Cratiointhiscomparison, establishes thebenchmarkofoneseaturtletakeper190,000kgof fish. Thesignificantprogressinthisfisheryinreducingseaturtle bycatchisdepictedclearlyinthecomparisonofB/Cratios Table1 Estimates ofCPUE,seaturtleBPUEandbycatchtocatch(B/C)ratiosforWesternPacificlonglinefisheriestargetingtuna/mixedspecies. Longline fishery Hook depthandseaturtle populations impacted CPUE BPUE B/C Operating withinWCPFCconventionareabyflag,targeted fish, andgenerallatitude Targetfishmt/ 10,000hooks Sea turtletakes/ 10,000hooks (BPUE/CPUE) Hawaii(US):bigeye,yellowfin,albacoretuna;Sub-tropical central NorthPacific Hook depth:43–400m 1.9[a] 0.01[b] 0.005 North Pacificloggerheads,western Pacific leatherbacks Hawaii(US):swordfish;Sub-tropicalandtemperatecentral North Pacific(after2004managementregime) Hook depth:21–70m9.7[c] 0.19[d] 0.02 North Pacificloggerheads,western Pacific leatherbacks Japan: bigeye,yellowfintuna;TropicalPacificfisheryHookdepth:45–400m3.60[e] 0.09[f] 0.025 WesternPacificgreens,oliveridleys Eastern Australia:swordfish,tuna,s.marlinEastern Australia Hook depth:35–50m4.8[g] 0.24[h] 0.05 Southwest Pacificloggerheadsand greens Taiwan:offshorefishery,bigeye,yellowfintuna,billfish; TropicalPacificfishery Hook depth:35–250m3.30[i] 0.24[j] 0.073 WesternPacificgreens,oliveridleys China: bigeye,yellowfintuna,billfish;TropicalPacific Fishery Hook depth:35–120m2.40[k] 0.24[j] 0.1 WesternPacificgreens,oliveridleys [a] Averageofnumberofalbacore,bigeyeandyellowfintuna/10,000hooksfor2003–2005.2005averagecalculatedfromWesternPacificlonglinelogbooksummaryfor 1/2005through12/2005,vesselslandingorbasedinHawaii,tunatrips, X averageweightoffishperspecies,2005,fromRussellIto,FisheriesMonitoringand Socioeconomics Division,NOAAFisheriesPIFSC.2003and2004averagescalculatedfrompp.3–49,tunatripCPUE(fishper1000hooks),pp.3–49,PelagicFisheriesofthe WesternPacificRegion2004AnnualReport,WesternPacificRegionalFisheryManagementCouncilJune2005 X averageweightoffishperspecies2003and2004,from Russell Ito,FisheriesMonitoringandSocioeconomicsDivision,NOAAFisheriesPIFSC. [b] PacificIslandsRegionalObserverProgram,HawaiiDeep-SetLonglineFisheryAnnualStatusReports2003–2005,NOAAFisheriesPIRO. [c] Averageof2004and2005estimates.2004estimatecalculatedfromWPRFMC,2004.Pelagicfisheriesofthewesternpacificregion,2002AnnualReport.Honolulu,HI (averageswordfishCPUEandaverageswordfishweightestimatefor2004,pp.3–50andTable62005).2005estimatecalculatedfrom2005CPUEcalculatedfromWestern Pacific longlinelogbooksummaryfor1/2005through12/2005,vesselslandingorbasedinHawaii,swordfishtrips X 2005averageswordfishweightestimatefromRussell Ito, FisheriesMonitoringandSocioeconomicsDivision,NOAAFisheriesPIFSC. [d] Sea turtlecaptureratesbytheHawaiiswordfishlonglinefisheryafterregulationsdesignedtoreduceseaturtleinteractionscameintoeffectbefore'' (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 deploy- ment of hooks. The present sea turtle bycatch by this fleet, therefore, is likely to be lower than the B/C ratio in Fig. 2.