

# Alternative methods to spatially distribute fishing effort within the Hawaiian longline fishery and corresponding effects on the calculation of bycatch rates

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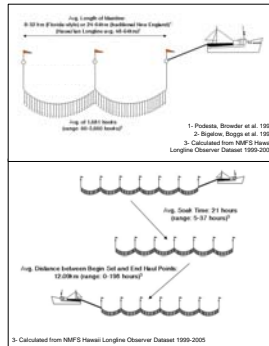
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## Abstract

Bycatch in longline fisheries has been recognized as a threat to many endangered populations of sea turtles. The precipitous decline of such populations as the Pacific leatherback (*Dermochelys coriacea*), has made the understanding of fisheries interactions a research priority for the sea turtle conservation community. The economic and social importance of the fisheries involved has also led to numerous studies that use or investigate the spatial distribution of longline fisheries effort to understand catch and bycatch rates. These analyses generally ascribe effort from an individual longline set to the point at which the gear is deployed or hauled. Typically, reported fishing effort summarizes these point values over large areas (>1°). Although assigning kilometers of longline effort to a single point may be sufficient for large-scale summaries of general fishing effort, the accuracy of finer-resolution models, such as those associating local oceanographic effects to catch or bycatch rates, may be strongly influenced by the distribution method. In this assessment, we look at alternative techniques (i.e. the use of centroids, polylines, and polygons) for distributing the fishing effort of the Hawaiian longline fleet. We analyze the effect of scale on the different distribution schemes and make recommendations regarding which methods for distributing fishing effort are appropriate based on the desired resolution of the parent model. This study is part of Project Global (<http://bycatch.env.duke.edu>), a global fisheries bycatch research initiative funded by the Gordon & Betty Moore Foundation.

## Introduction

Recent studies have highlighted the impact of various fisheries on endangered marine megavertebrates. Pelagic longline fisheries in particular have undergone deep scrutiny. (Bolten et al. 1996, Bjørndal et al. 1999, Lewison et al. 2004). Pelagic longline bycatch may have played a role in the severe (80% & 95%) decline in the population of nesting Pacific Loggerheads (*Caretta caretta*) and Leatherbacks (*Dermochelys coriacea*) over the last 20-25 years (Limpus 2003, Spotila et al. 2000). The possible implication of longline fisheries in the decline of endangered populations of non-target species has led to a number of closures and/or the placement of stringent management measures (Gillman et al. 2006). It is in the interest of both the fishing industry and the conservation community to gain a better understanding of these bycatch events. The oceanographic characterization and modeling of bycatch events should therefore be a prime commercial and conservation objective.



## Confounding factors in modeling bycatch:

- Exact location of fishing gear or a bycatch event is generally unknown
- Fishing effort is usually ascribed to the point at which the longline set begins
- Longline gear may span 10s of kilometers, limiting fishing effort/bycatch studies to be summarized at large scales (≥ 1°) studies

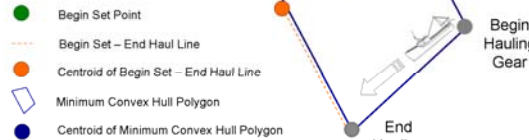
## New opportunities for characterizing bycatch events:

- Alternate methods for distributing fishing effort
  1. Polylines (i.e. from the beginning of the set to the end of the haul)
  2. Polygons (i.e. Minimum Convex Hulls using known fishing points)
- High resolution remotely sensed oceanographic data (1km – 9km)

## Goals:

- Use minimum convex hulls to describe fishing sets
- Examine correlation between distribution methods at different scales
- Recommend distribution methods based on the resolution of the potential study

## Longline Effort Distribution Methods



## Methods

- 5 Methods of distributing longline effort were examined (see figure above)

- Lines were created and centroids taken using XTools extension for ArcGIS 9.x (<http://www.xtoolspro.com>)
- Minimum Convex Hulls were created using Hawth's Tools extension for ArcGIS 9.x (<http://www.spatial ecology.com/htools>)

- These distribution methods were examined at 7 scales:

-5 degree -1 degree -30 km -15km  
-9 km -4 km -2 km

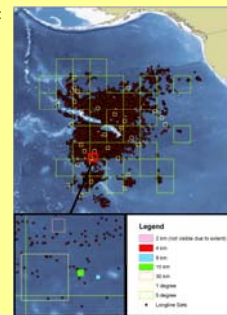
- 30 gridcells were randomly selected at each scale.

- Effort was calculated for lines and polygons by dividing the part that fell within the cell by the total length or area of the set and multiplying that by the number of hooks in the set.

- Effort for each cell was summed for each distribution method at each scale.

- Spearman's Rank Sum correlation statistic was used to compare summed effort values within each gridcell.

- A Friedman Test/Dunn's Test will also be run to determine whether there are significant differences between the values.



Sets in the Hawaiian longline fishery from 1999-2005 and randomly selected gridcells at 7 scales.



## Acknowledgements

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## Results

- A strong correlation between distribution methods was exhibited at large scales (>15km).

- Virtually no correlation found between distribution methods at fine scales (<9km)

- At finer scales (<15km), point distribution methods resulted in large variability – most values were either 0 or very large.

- Using the MCH distribution method resulted in lower variability than the other methods at fine scales (<15km).

Scale	Method	Set Point	Line Centroid	MCH Centroid	Line	MCH
5 Degree	Set Point	1.000	0.999	0.999	1.000	0.999
	Line Centroid	0.999	1.000	0.999	0.999	0.999
	MCH Centroid	0.999	0.999	1.000	0.999	0.999
	Line	1.000	0.999	0.999	1.000	0.999
	MCH	0.999	0.999	0.999	0.999	1.000
1 Degree	Set Point	1.000	0.999	0.999	0.999	0.999
	Line Centroid	0.999	1.000	0.999	0.999	0.999
	MCH Centroid	0.999	0.999	1.000	0.999	0.999
	Line	0.999	0.999	0.999	1.000	0.999
	MCH	0.999	0.999	0.999	0.999	1.000
30 km	Set Point	1.000	0.999	0.999	0.999	0.999
	Line Centroid	0.999	1.000	0.999	0.999	0.999
	MCH Centroid	0.999	0.999	1.000	0.999	0.999
	Line	0.999	0.999	0.999	1.000	0.999
	MCH	0.999	0.999	0.999	0.999	1.000
15 km	Set Point	1.000	0.999	0.999	0.999	0.999
	Line Centroid	0.999	1.000	0.999	0.999	0.999
	MCH Centroid	0.999	0.999	1.000	0.999	0.999
	Line	0.999	0.999	0.999	1.000	0.999
	MCH	0.999	0.999	0.999	0.999	1.000
9 km	Set Point	1.000	0.999	0.999	0.999	0.999
	Line Centroid	0.999	1.000	0.999	0.999	0.999
	MCH Centroid	0.999	0.999	1.000	0.999	0.999
	Line	0.999	0.999	0.999	1.000	0.999
	MCH	0.999	0.999	0.999	0.999	1.000
4 km	Set Point	1.000	1.000	0.999	0.999	0.999
	Line Centroid	1.000	1.000	0.999	0.999	0.999
	MCH Centroid	0.999	0.999	1.000	0.999	0.999
	Line	0.999	0.999	0.999	1.000	0.999
	MCH	0.999	0.999	0.999	0.999	1.000
2 km	Set Point	1.000	-0.111	-0.062	0.468	-0.198
	Line Centroid	-0.111	1.000	0.010	0.572	-0.120
	MCH Centroid	-0.062	0.010	1.000	0.302	-0.295
	Line	0.468	0.572	0.302	1.000	0.193
	MCH	-0.198	-0.120	-0.295	0.193	1.000

## Conclusions

The strong correlation exhibited at large scales (>15km) validates the use of point distribution methods for coarse resolution analyses. Conversely, the breakdown in correlation between distribution methods at fine scales (<15km) highly suggests that the choice of distribution method at these scales is extremely important. These results do not inherently mean that the use of minimum convex hulls (or other polygon distribution methods) are a better representation of fishing effort at fine scales. The argument for such distribution methods in fine resolution studies is best made by the descriptive statistics of the gear itself as laid out in the introduction. When a single point is used to allocate fishing effort, all the effort is associated with one gridcell regardless of its size. The ascription of all effort of a 20-60km longline that may have drifted an equal distance overnight to a single 2 km<sup>2</sup> cell will likely result in the overestimation of effort in that cell and the corresponding underestimation of effort in surrounding cells. Since a bycatch rate is the number of species caught per unit of effort, such a miscalculation of effort would result in erroneous bycatch rates – again, over-attributing bycatch to a specific cell. Thus, we recommend the use of polygon distribution methods like minimum convex hulls for fine resolution (<15-30km) analyses. Exceptions to this rule exist where the bycatch event is generally associated with setting or hauling of the fishing gear (i.e. for seabird bycatch studies). In an effort to provide further guidelines for marine spatial modeling of fisheries and bycatch, we will be following this study up with an analysis of autocorrelation within remotely sensed oceanographic datasets.

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