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CPUE time series from the California Driftnet Fishery, 1985-Present

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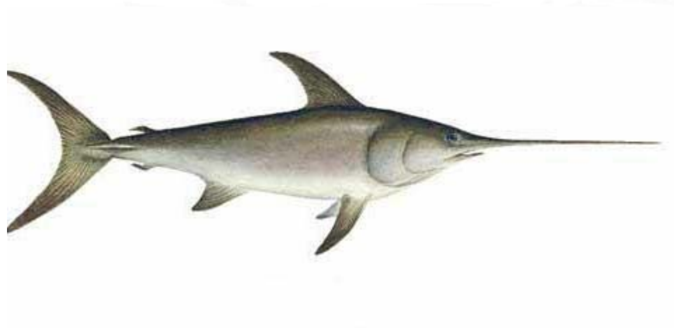

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Abstract

Drift gill net fisheries targeting swordfish have operated off the west coast of the United States since the early 1980's. Management regulations have impacted both the method and area of operation in attempts to reduce impact on non-targeted species. The fishery has been somewhat stable in operations since 1985 when ratios of swordfish to shark landings were lifted. A CPUE series was derived from 1985-2008 from logbooks recording catch and effort data. The time series show a population that has varied but with no sustained long-term trend. The index appears to be an improvement over a previous version as some of the inter-annual variability has been removed and the series was extended back in time. However, if used for stock assessment it is our recommendation that a separate *q* be estimated for the period after 2000.

Introduction

Overview of gillnet fisheries

Gillnet operations off the coast of California (USA) are comprised of both set-net and drift-net fisheries. Set-nets typically take demersal species in inshore waters while drift-net fisheries capture pelagic species from farther offshore. The drift-net fishery has historically targeted sharks (thresher and mako) and swordfish, but have included other larger species such as opahs and tunas. The fishing vessels typically range in size from 30-75 feet with an increasing trend in size which may be associated with shift in fishing patterns to more offshore banks. Fishing trips have varied in duration from one night to more than a month (Diamond et al. 1986). Market factors, fish holding facilities and weather conditions all impact the duration of fishing activity. The majority of drift-net fishing has taken place in southern and central California; however there has been an expansion of fishing effort as far as the Canadian border.

The drift-net fishing gear is comprised of float line (buoyed) and lead line with mesh panels hanging between. Mesh size has ranged from 13-22 inches stretched, but the average size has been relatively constant (19-22 in) since 1985-1986 (Hanan et al. 1993). Nets are typically between 800-1000fm (a fm=6ft) in length and could be fished near the surface to as deep as 30m by lengthening buoy lines. Fishing normally takes place at night, with nets set before dusk and retrieved by morning.

Management measures affecting fishery

Beginning in 1980, swordfish were first allowed to be landed and sold from the drift-net fishery during a specific portion of the year. However, those landing were assumed to be non-targeted catch. In 1982 direct targeting of swordfish was allowed over part of the year and mesh size was increased to 14 inches, a maximum of 150 permits were issued and time/area closures were used to control marine mammal interactions. In 1984 an additional 35 permits were issued for fishing north of the traditional fishing areas of the southern California bight. In 1985 a requirement of equal shark/swordfish catch was lifted. In 1986 fishing in the northern areas was restricted to outside 12 nm. In 1989 gill net fishing inside 75 nm of the mainland was restricted for May-mid July. In 1990 the National Marine Fisheries Service began placing observers on vessels to monitor marine mammal interactions (Carretta and Enriquez 2006). In 1997 acoustic devices (pingers) and net extenders (extend the distance of floatline from surface by 11m) became mandatory on nets to reduce mammal bycatch (Carretta et al. 2005). In addition, season/area closures have been instituted after 2000 to reduce turtle encounters.

Previous work

At the 2008 ISC billfish WG meeting in Honolulu, Hawaii a paper (Piner and Betcher 2008) presented the first analysis on swordfish CPUE from the driftnet fishery. The index was calculated from 1991-2008 because that period a fraction of the total fleet trips was covered by observers. The index also included multiple explanatory factors, including water depth, net depth, season and latitude. The working group recommended that the authors continue to explore the data and attempt to extend the index back to the earliest phase and give some consideration to possible effects that caused an artificial increase in CPUE post 2000.

Objectives

The objectives of this paper were to use the working group recommendations (cite wg report) to improve the time series of standardized Catch per Unit Effort (CPUE) from the directed swordfish drift-net fleet. In addition, other changes were included that we felt improved the reliability of the series.

Materials and Methods

Data source and fields

Data for this project has come from a mandatory logbooks program which began in 1980 (Huppert and Odemar 1986). Logbook reporting after the first year of implementation has generally been assumed to be good (Miller et al. 1983, Beeson and Hanan 1991) with reported catch of swordfish being 90-120% of the landed level (Hanan et al. 1993). In the first year of the program reporting was low (<10%) due to difficulties in implementing of the program. Information in the logbooks includes, target species, catch by species (landed and released and unknown), vessel identifiers, target species, set number, fishing time and location. All were potential factors to be investigated for inclusion with the CPUE modeling. Only trips targeting swordfish were used in the subsequent analysis. The sampling unit was defined as a net set by a specific vessel on a single night.

Modeling methods and Model selection

A delta approach (Lo et al. 1992; Stefánsson 1996) was used to model CPUE. The proportion of positive observations was modeled using a binomial error assumption and the catch rate of positive observations using the best fitting of several different error distributions (gamma, lognormal etc.) A range of fishing and oceanographic factors were considered for inclusion the model. Evaluation of the importance of factors was based upon explanation of deviance and parameter significance. Factors investigated included season (winter Dec-Feb, Spring Mar-May, Summer June-Aug and Fall Sept-Nov), latitude (2 blocks 30-37^{o}N and >37^{o}N), longitude (4 degree blocks), Gear depth (2 blocks- <15m, >15m), and water depth (3 blocks -0-600m, 600-1000m, and1000m). Years from 1985-2008 were included in the analysis. Because the fishery is a winter fishery, observations from season 4 are considered part of the next year. Effort was calculated as hours the product of the hours fished and net length (fmhrs).Catch is recorded as numbers of fish caught (landed and released).

The initial model used to estimate CPUE in both proportion positive and positive catch rate was as follows:
Y_{ijklm}=mean +$year_i$+$geardepth_j$+$latitude_k$+$season_l$+$waterdepth_m$ + $Error_{ijklm}$

However, it was determined that the factors of geardepth and waterdepth include many missing observations. These missing observations resulted in many records being removed from the analysis. Thus a decision was made to eliminate these factors and the new simplified model was as follows:

Y_{ikl}=mean +$year_i$+$latitude_k$+$season_l$+ $Error_{ikl}$

The final estimate of the annual abundance index was the product of the back transformed marginal year effects (Searle 1980), corrected for the log bias in the lognormal back transformation. The variance estimates were obtained by jackknifing the data (Dick pers comm.).

Results and Discussion

Data characteristics

The driftnet fishery has operated across the entire length of the US west coast (Figure 1). Although data existed from 1981-2008 we did not use data from the early 1980's because of the rapidly changing regulations on the developing fishery. The most notable changes included mesh size and the allowance of direct targeting of swordfish. In addition we restricted the data to only those observations above 30^{o}N because of a lack of positive observations below 30^{o}N. Sample size was much larger in the early part of the time series (Table 1) as effort has decline nearly linearly until present.

Regression results and diagnostics

The time series of CPUE was without a long-term trend (Figure2) with increased uncertainty in the last years due to diminishing effort and therefore a reduction in sample size (Table 2). However, due to the large total sample size (~50,000; Table 1) the estimated variance is quite small (Table 2; Figure 2). Model diagnostics indicated reasonable performance of the lognormal error assumption (Figure 3), although some level of model misspecification and unequal variance is apparent. Although, AIC criteria strongly favored the lognormal model for estimating catch rates, the estimates of CPUE from alternative error assumptions were generally quite similar with alternative error assumptions.

General discussion

In our initial analysis we postulated that increasing uses of time/area closures as well as unknown consequences of pingers and nest extenders cause some concern about the constancy of the catchability assumption after 1997. However, it appears that the some of the increased inter-annual variability and the dramatic increase in CPUE post

2000 were due to the elimination of observations that did not contain records of water depth or gear depth (Figure 4). This was magnified because of the declining effort after 2000. In this new analysis we do not eliminate those records and the post 2000 increase is not as appreciable and is within the range of the observation from the extended series. However, due to the spatial changes in the fleet we would still recommend that when using this series for stock assessment that estimating a separate q for the period post 2000 is advisable. If the series is used without estimating a separate q for the post 2000 period, we recommend that if the se are inflated (via iterative re-weighting or estimation of additional variance inside the model) that the relative uncertainty of the latter data points be propagated.

The new GLM appears more similar to the nominal CPUE, while controlling for the large increase in CPUE at the end of the time series (Figure 5). We also note that by including season 4 (Oct-Dec) as part of the next year (year +1) we more explicitly link the seasons with highest catch rates and the index should be representative of January in the stock assessment model. The new index appears to be an improvement on the one presented in February because the inter-annual variability is much reduced and the implied changes in population abundance appear much more reasonable (Figure 6).

The construction of this new CPUE series balanced inclusion of all data against use of explanatory factors. In this case we felt it better to use all the data than the factors of gear depth and water depth, despite their statistical significance. It may be possible in future work to use all the data and include all factors through the use of a random effects model. This would essentially assume that all missing observations are random with respect to the fishing process. It was not possible to evaluate this assumption at this time. However, this is an area for future work. To extend the time series back to the start of the data (1981), it will also be necessary to quantify the effects of mesh size, and targeting changes on catch rate of swordfish. There is some data on mesh size in the current logbook, so it may be feasible to understand this process, but it is unlikely that the effects of targeting switching from thresher shark to swordfish (due to management regulation) could be estimated. An additional improvement will be to treat sets from the same vessel/day as replicate observations of the CPUE of the vessel instead of independent observations of the population catch rate. This is unlikely to change the estimated time series, but may affect the estimates of variance due to a reduction in sample size and reduction in correlation between some observations. Even without these additions, this manuscript presents an improved estimate of CPUE for the driftnet fishery.

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Table 1. General statistics of the CPUE (fmhrs)data used in this work.

year	N	Mean	Std	Minimum	Maximum
1985	3149	0.000153	0.000282	0	0.0035
1986	5003	0.000288	0.000436	0	0.00625
1987	5709	0.000199	0.000231	0	0.002281
1988	4137	0.000161	0.000201	0	0.002667
1989	2955	0.000206	0.000277	0	0.002917
1990	2480	0.000166	0.000268	0	0.003167
1991	1934	0.000209	0.000309	0	0.002818
1992	1717	0.000203	0.00028	0	0.002636
1993	2130	0.000269	0.000357	0	0.003833
1994	2717	0.000184	0.000223	0	0.0024
1995	1748	0.00015	0.000199	0	0.0022
1996	2143	0.000216	0.000329	0	0.005714
1997	1584	0.000204	0.000275	0	0.002667
1998	1873	0.000242	0.000396	0	0.01
1999	1190	0.00021	0.000273	0	0.002
2000	1319	0.000196	0.000244	0	0.0023
2001	660	0.000193	0.000302	0	0.001875
2002	801	0.000171	0.000261	0	0.002222
2003	881	0.00014	0.000238	0	0.0022
2004	699	0.000194	0.000287	0	0.002417
2005	576	0.000251	0.000454	0	0.008889
2006	647	0.000356	0.000591	0	0.011111
2007	809	0.000385	0.000724	0	0.012222
2008	397	0.000745	0.004481	0	0.069444

Table 2. Estimated CPUE and CV.

year	CPUE (fmhrs)	CV
1985	0.000175	0.04
1986	0.000187	0.03
1987	0.000130	0.03
1988	0.000095	0.04
1989	0.000111	0.04
1990	0.000073	0.05
1991	0.000099	0.05
1992	0.000091	0.05
1993	0.000114	0.04
1994	0.000076	0.04
1995	0.000058	0.05
1996	0.000096	0.04
1997	0.000096	0.05
1998	0.000116	0.04
1999	0.000102	0.05
2000	0.000094	0.05
2001	0.000078	0.08
2002	0.000079	0.07
2003	0.000059	0.07
2004	0.000084	0.07
2005	0.000135	0.07
2006	0.000191	0.07
2007	0.000209	0.06
2008	0.000184	0.09

Data Investigation

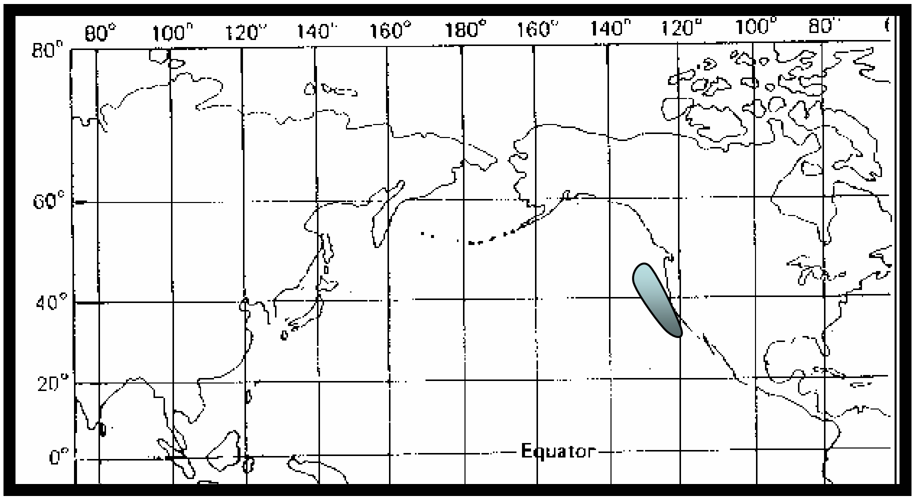

Figure 1. Spatial distribution of fishery data in relation to the north Pacific ocean.

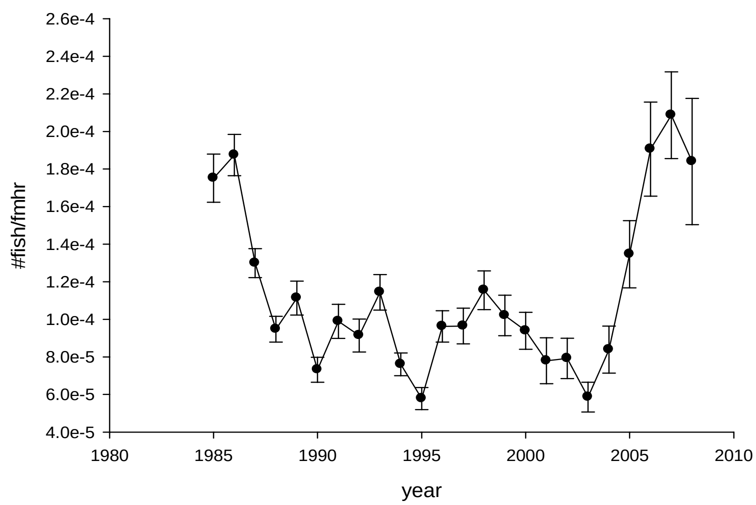

Figure 2. The estimated CPUE from 1985-2008 and associated 95% CI ` from the jackknife.

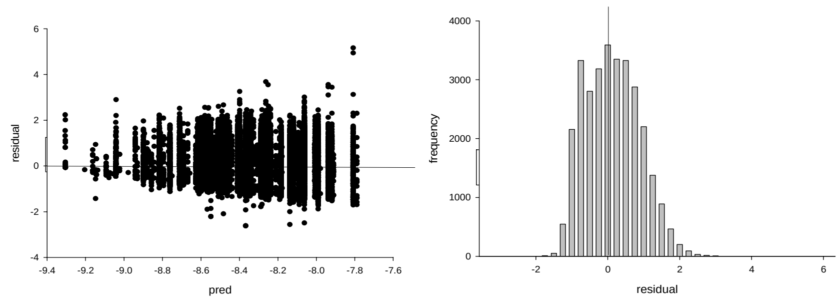

Figure 3. a) Plot of predicted positive catch rate against the residual, and b) histogram of residuals. The solid line is 0 residual.

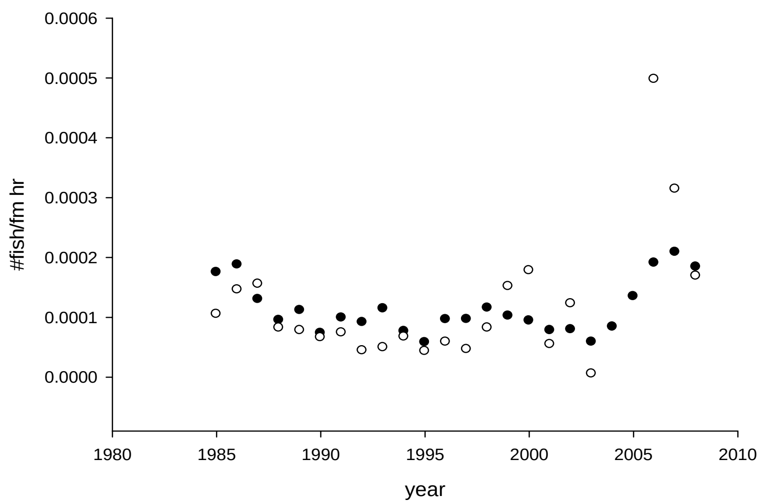

Figure 4. The estimated CPUE from the driftnet fishery using all explanatory (○) variables and the reduced model (●).

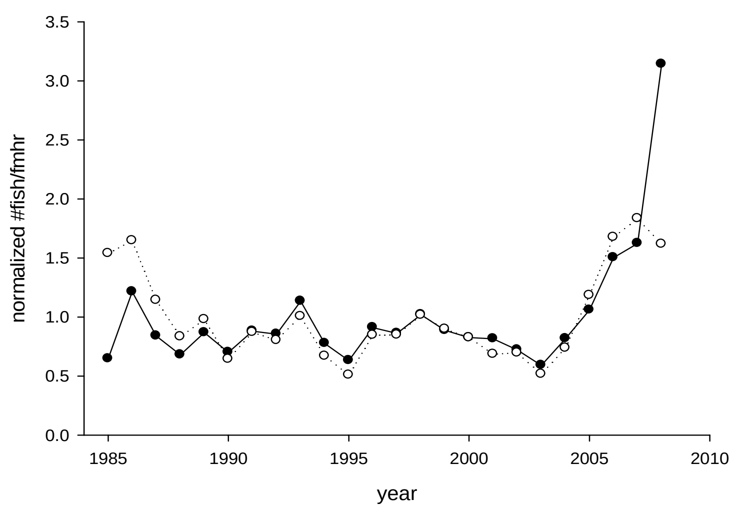

Figure 5. The estimated CPUE from the driftnet fisheries using nominal (●) and glm (○).

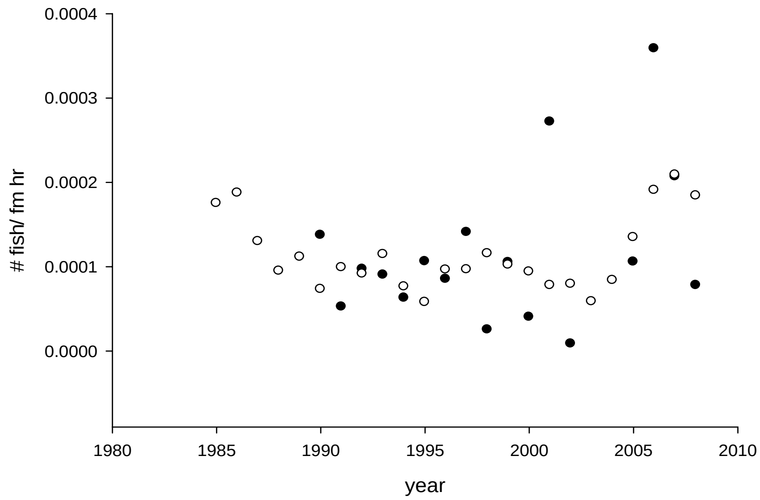

Figure 6. The estimated CPUE from the driftnet fishery from the previous working paper (●) and from the current working paper (○).