An Evaluation of Codend Mesh Selectivity in the *Loligo pealai* Squid-Directed Fishery: A Commercial-Scale Test

By

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Introduction

- *Loligo pealei* - life span is < one year
  - Fast growth rate
- Migrate inshore in late spring (May-June)
  - Support inshore commercial trawl fishery in summer
- Migrate offshore late fall (Nov–Dec)
  - Reside on continental shelf Jan-April
  - Support offshore commercial trawl fishery

Introduction

- ***Loligo* fishery uses a 1.875" mesh codend**
  - **Trawl during daylight hours on the bottom**
- **Some of the highest discards in the *Loligo* squid fishery is *Loligo* itself**
  - **Most are < marketable size**
    - **Marketable size is $\geq$ 10 cm**
- **Other important discard species are**
  - **Butterfish (*Peprilus triacanthus*)**
  - **Scup (*Stenotomus chrysops*)**
  - **Silver hake (*Merluccius bilinearis*)**

Objective

- To determine if an increase in codend mesh size from present legal size of 1.875" (4.76 cm) can reduce capture of submarket-size squid, butterfish, silver hake, and other species of concern without impacting catch of market-size squid under commercial-scale fishing

Methods

- **Vessels were of similar size, fished similar standard gear**
  - **Varied mesh size**

	Hull Length	Net Type	Ground Cable	Headrope	Footrope	Control Codend	Experimental Codend
Vessel I	23.47 m	Millionaire	44.20 m	44.20 m (wire/rope)	82.30 m (cable/wire)	Single twine diamond hung 4.92 -cm mesh with a 15.10 -cm mesh strengthener	Single twine diamond hung 6.2 6-cm mesh with a 15.14 -cm mesh strengthener
Vessel II	22.89 m	Millionaire	41.15 m	41.15 m (rubber cookies)	82.30 m (cable/wire)	Single twine diamond hung 4.92 -cm mesh with a 15.11 -cm mesh strengthener	Single twine diamond hung 6.46 -cm mesh with 15.26 -cm mesh strengthener
Vessel III	22.40 m	Millionaire	41.15 m	41.15 m (rubber cookies)	82.30 m (cable/wir e)	Single twine diamond hung 4.92 -cm mesh with a 15.11 -cm mesh strengthener	Single twine diamond hung 6.46 -cm mesh with a 15.26 -cm mesh strengthener

Methods

- Two vessels fished in parallel under standard commercial conditions
  - Towed legal codend mesh 1.875“ (A)
  - Towed experimental codend mesh 2.5" (B)
- Fished in offset ABBA sequence to permit pairwise comparisons over 4 tow sequence
  - A_1A_2, B_1B_2, A_1B_2, B_1A_2

Methods

- Depth, locations, and gear deployment were standard for fishery
- Tows did not exceed 3 hours (often commercial tows > 3 hours)
- Parallel tows were equivalent in duration
- Tow speeds 2.9-3.2 knots (standard)
- Forty tows taken during February-April 2005
- Forty tows taken during December 2005

Methods

- One vessel incurred major damage and was unavailable for 2nd half of study
  - Replaced with another vessel
- Vessel position and time recorded in 1-minute intervals for each tow using DGPS
- Vemco data recorder measured water temperature and depth every minute of tow
  - Used to determine time-on-bottom and time-off-bottom
  - Did not use door spread or net height sensors on all vessels

Methods

- For each tow, catch was sorted and weights obtained for all caught species
  - Used NMFS-approved subsampling protocols
- Target species for length measurements
  - *Loligo* squid, scup, silver hake, butterfish, black sea bass, summer flounder, and male and female spiny dogfish
- 100 randomly selected lengths obtained for each tow

Statistical Analysis

- Found differences in magnitude of total catch on each cruise due to temporal differences in squid availability
- To control for influence of time-of-year and consequent changes in locations fished, catch weight/tow for each species was standardized across all cruises using the species' global median catch weight with legal 1.875" mesh codend

Statistical Analysis

$$C_{STD} = \frac{C_{Global} C_{Ti}}{C_T}$$

C_{STD} =standardized catch weight for a given species in kg/tow

C_{Global} =global median catch weight/tow for that species

C_{Ti} =species catch weight for trip T, tow *i*

C_T is the within-cruise median catch weight/tow on trip *T*

- Used same method for number of individuals replaced catch weight for catch in numbers

Statistical Analysis

- ***A posteriori* examination with ANOVA confirmed no significant time-of-year effects after standardization**
- **Binned species based on size classes of interest**
  - ***Loligo* <10 cm (small), 10-13 cm (medium) and ≥ 13 cm (large)**
  - **Dealers wanted to retain squid ≥10 cm and eliminate squid <10 cm**

Statistical Analysis

- **Vessels fished in parallel so difference in standardized catch weight between simultaneous tows was calculated for four pairwise net configurations**
  - **A_1A_2, B_1B_2, A_1B_2, B_1A_2**

Statistical Analysis

$Diff_{\text{AA or BB}} = C_{A1} - C_{A2}$ or $C_{B1} - C_{B2}$

$Diff_{\text{AB or BA}} = C_{A1} - C_{B2}$ or $C_{A2} - C_{B1}$

$Diff_{\text{AA or BB}}$ is difference in standardized species' catch weight (kg/tow) for given paired tow, both vessels towed same codend

$Diff_{\text{AB or BA}}$ is difference in standardized species' catch weight (kg/tow) for given paired tow with 1 vessel tow legal mesh and other vessel experimental mesh

C_{A1} and C_{A2} are standardized species' catch weight on vessel 1 and 2 with legal codend

C_{B1} and C_{B2} are standardized species' catch weight on vessel 1 and 2 with experim. codend

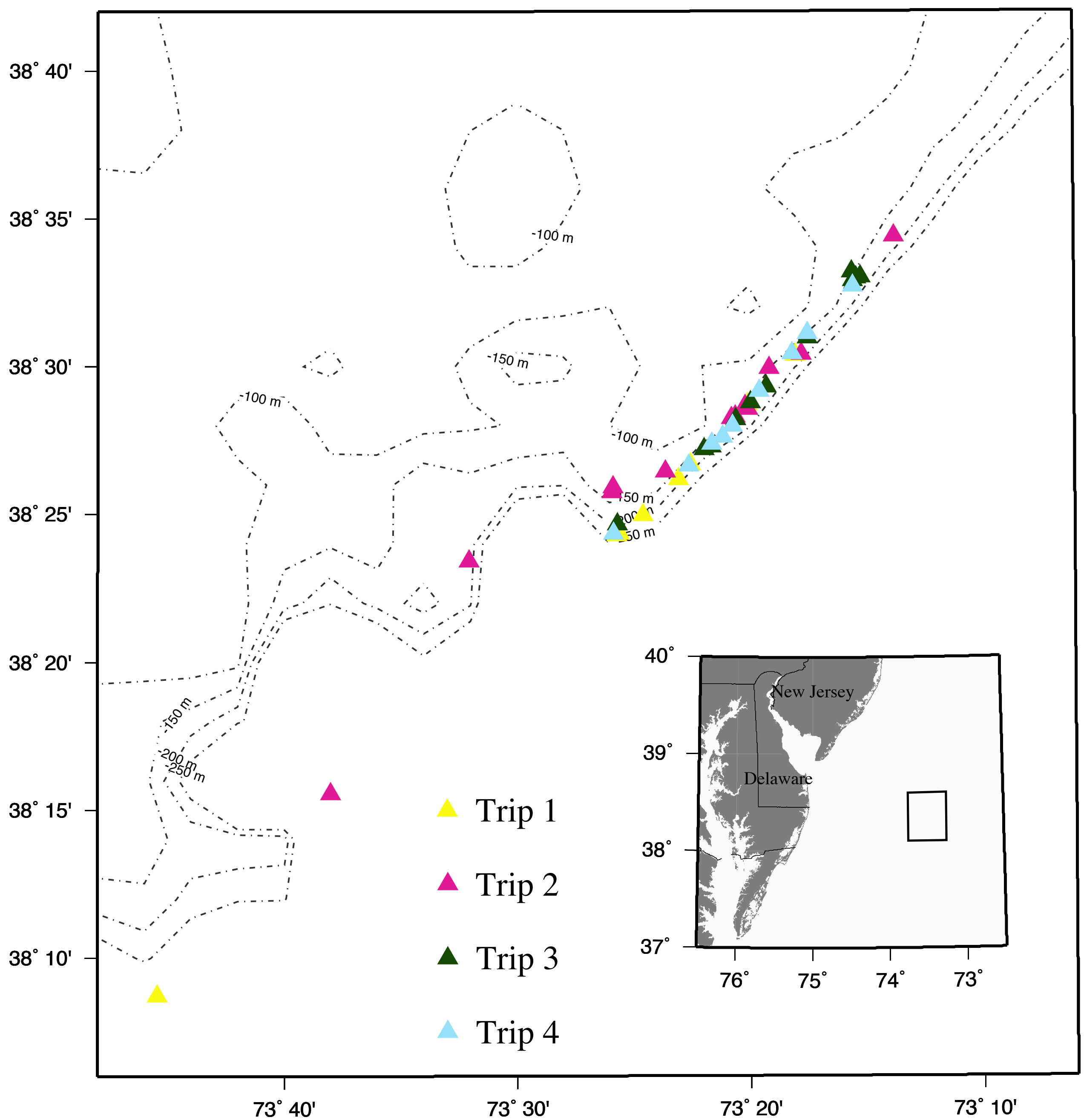
Statistical Analysis

- **Used nonparametric statistics because of variability between tows**
  - Evaluated differential performance of two vessels using the same gear by ranked ANOVA
  - Tested that the difference between the catches in a paired tow did not differ from zero with same codend type (AA or BB)
    - Two-tailed Wilcoxon Signed-ran test
  - Compared catches between paired tows with different codends (AB or BA)
    - One-tailed Wilcoxon Signed-ran test

Statistical Analysis

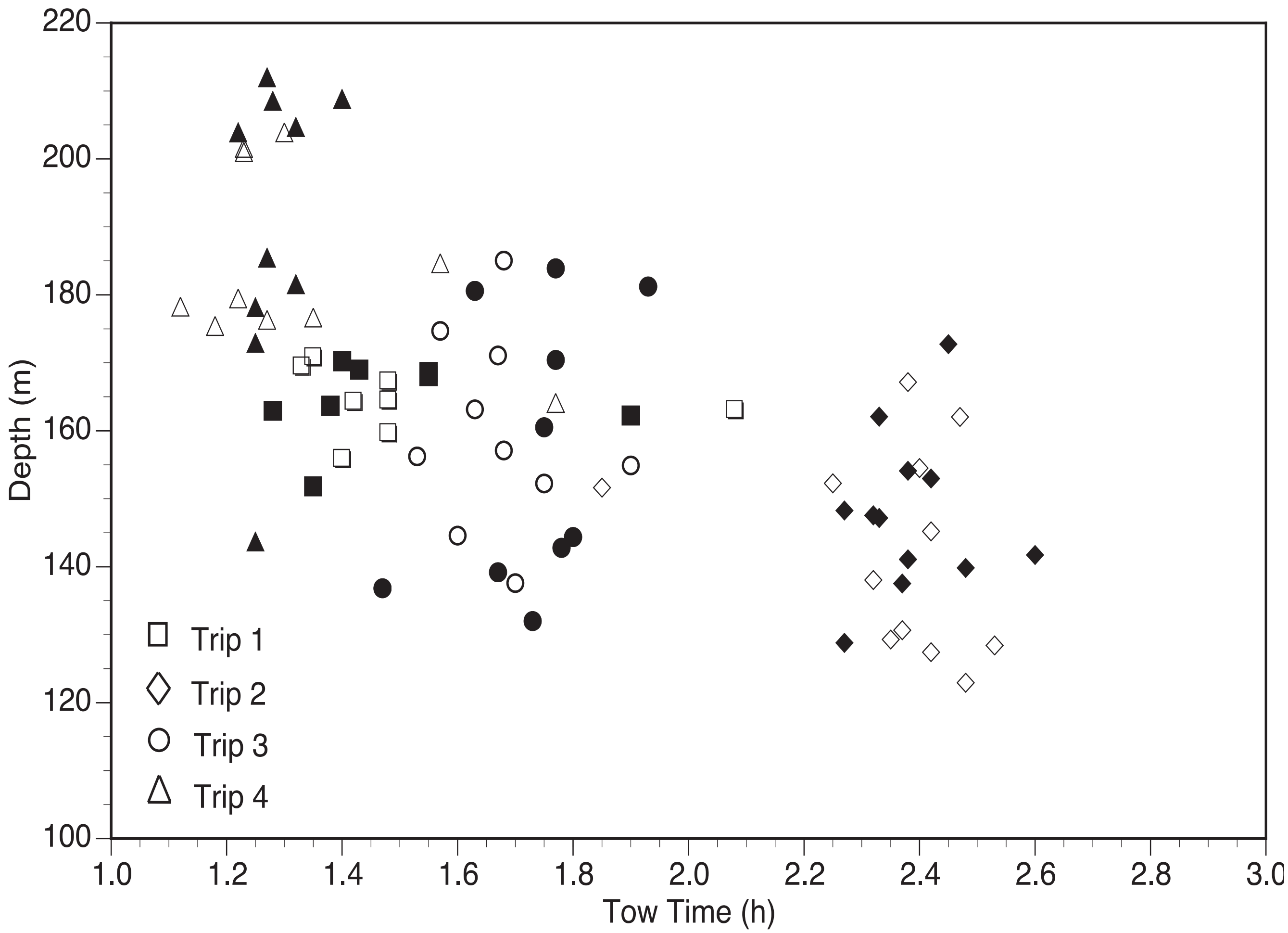
- Binomial test used to evaluate possible bias caused by a variable distribution in tow time or tow depth between tows with two codend mesh configurations
- *A posteriori* power analyses used to examine power of statistical tests comparing differences between codends

➢ Size-frequency distributions were computed for each species for each tow (mean size, 25^{th}, 50^{th}, and 75^{th} percentiles, the interquartile range and the range) and analyzed



38° 40'
38° 35'
38° 30'
38° 25'
38° 20'
38° 15'
38° 10'
73° 40'
73° 30'
73° 20'
73° 10'
-100 m
-150 m
-200 m
-250 m
Trip 1
Trip 2
Trip 3
Trip 4
40°
39°
38°
37°
76°
75°
74°
73°
New Jersey
Delaware

Date	Number of Tows	Tow Time (h)	Depth (m)	Tow Speed (km h^{-1})	Scope	Bottom Temperature (°C)	Total Catch (kg)
Trip 1: 26 -27 Feb							
Vessel I	8	1.49	162.8	5.15	3.06	12.1	3209.4
Vessel II	8	1.50	166.2	5.16	2.99	11.9	3701.4
Trip 2: 3 0 Mar - 1 Apr							
Vessel I	12	2.39	147.9	5.27	3.39	11.2	1775.9
Vessel II	12	2.35	142.4	5.20	3.56	11.4	1662.3
Trip 3: 12 -14 Dec							
Vessel I	11	1.69	173.9	5.17	2.88	11.8	2014.8
Vessel III	11	1.70	145.9	5.09	3.43	12.3	1412.5
Trip 4: 21 -22 Dec							
Vessel I	9	1.24	174.6	5.16	2.69	11.8	2161.8
Vessel III	9	1.29	202.4	5.00	2.26	11.9	1652.6

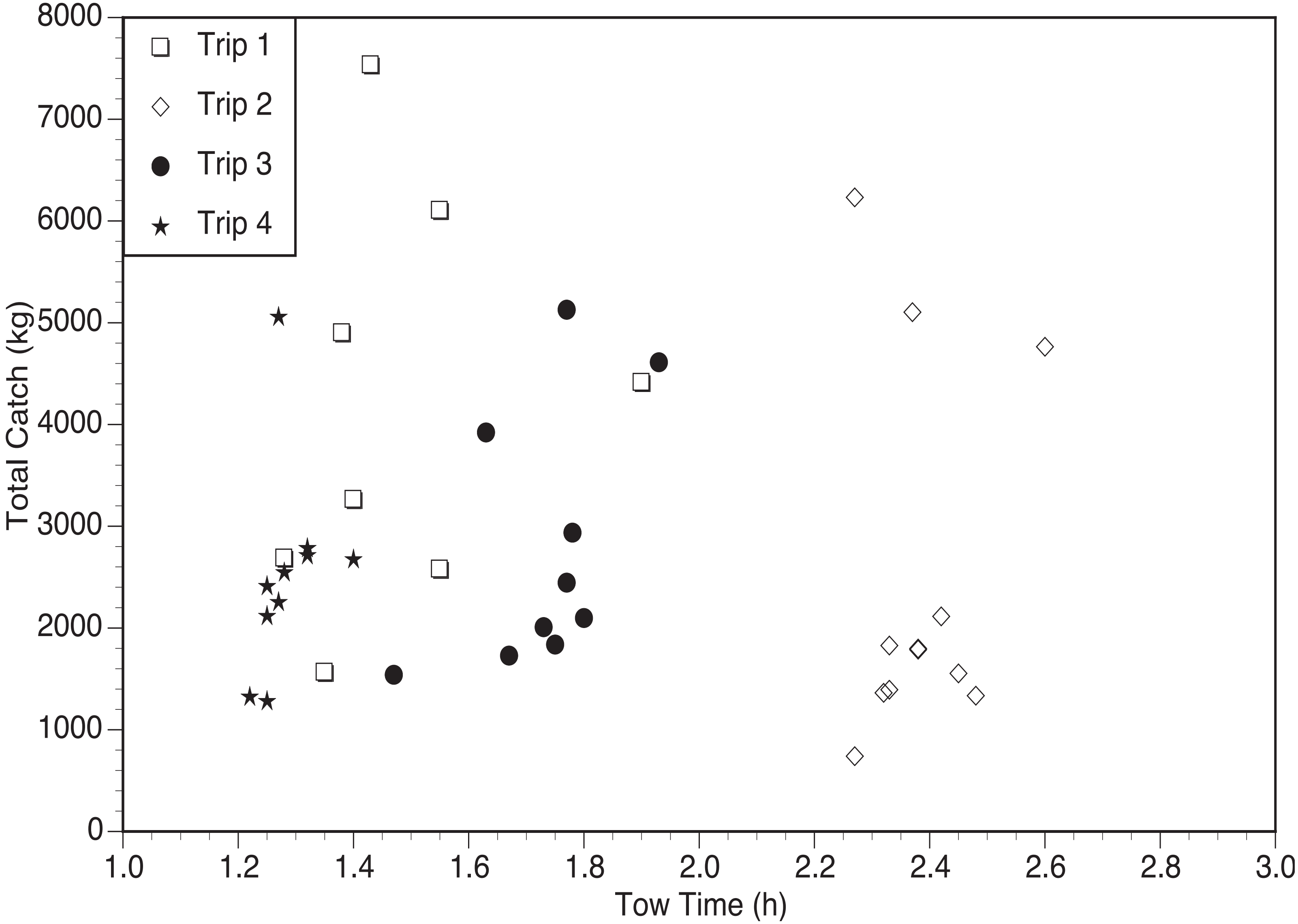


Control tows- solid symbols

Exp. Tows- open symbols

Four outliers: Trip1 - 2 long tow times, Trip 2 – 1 short tow, Trip 4 1 shallow tow; outliers considered part of normal variability and included in analysis

Total catch (kg) versus tow time (h) for tows using 1.875"



Results

- **Range of total catches observed during all trips was similar**
  - Spearman's Rank Correlation-Total catch weight increased significantly with tow time only for Trips 1 and 4 (alpha 0.05)
  - Tow times and depths were homogenously distributed above and below the trip median tow time and depth for the two codend configurations on each vessel (Binomial test)
  - Therefore, tow times and depths did not bias subsequent codend comparisons and variability retained as part of variance in data without further correction

Results

- Differences in tow times and depths between cruises part of overall cruise effect

➢ Cruise effects on catch weight and number in paired tows

- Median catch in weight and numbers varied considerably over cruises for *Loligo* squid
- After standardization of catch using ranked ANOVA – There were no significant differences in species-catch between cruises

Results

- **Differences in catch (weight & #s) between paired tows using same codend (A_1A_2 and B_1B_2)**
  - **Two vessels performed equivalently for *Loligo* squid when both were towing control codend (AA tows) or experimental codend (BB tows) based on ranked ANOVA**
    - **Result were for catch weight, number, and number by size**
      - **Therefore, vessel effects did not influence catch performance for *Loligo* in paired tows**
    - **Similar results for other species**

Results

- **Did the vessels catch equivalently?**
  - **Analysis of control tows (A_1A_2 and B_1B_2) indicated differences in *Loligo* catch (weight & #s) did not differ significantly from zero (Wilcoxon Signed-rank test)**
    - **Same true for small, medium, and large squid**
    - **Same true for exp. tows**
  - **Therefore, vessel performance during control and exp. tows was equivalent**

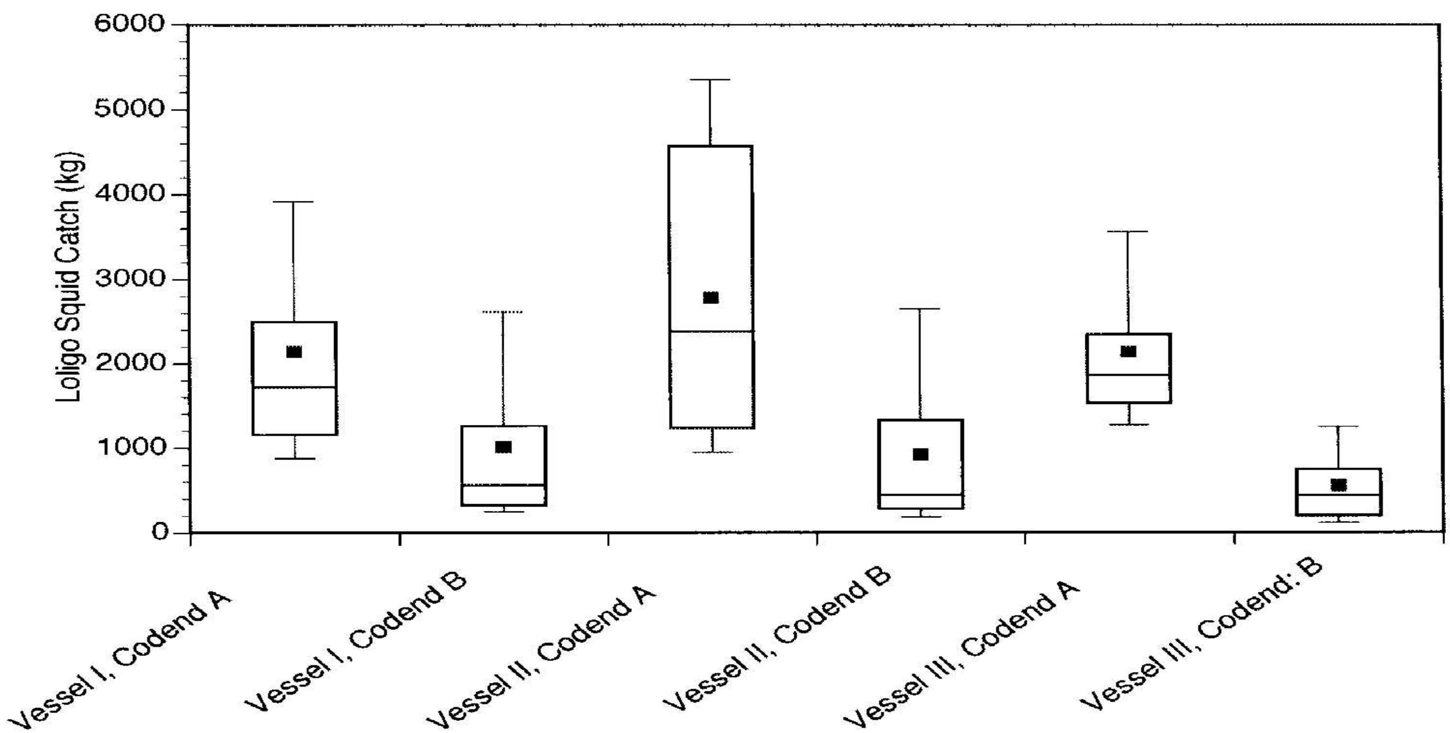
Results

- An evaluation of paired tows using different codends on each vessel (A_1B_2 and A_2B_1) ranked ANOVA
  - Relationship in catch between codends was equivalent regardless of which vessel towed the exp. codend and control codend
    - True for squid catch weight and numbers

➢ Effect of experimental codend on catch (weight & #s) in paired tows (A_1B_2 and A_2B_1)

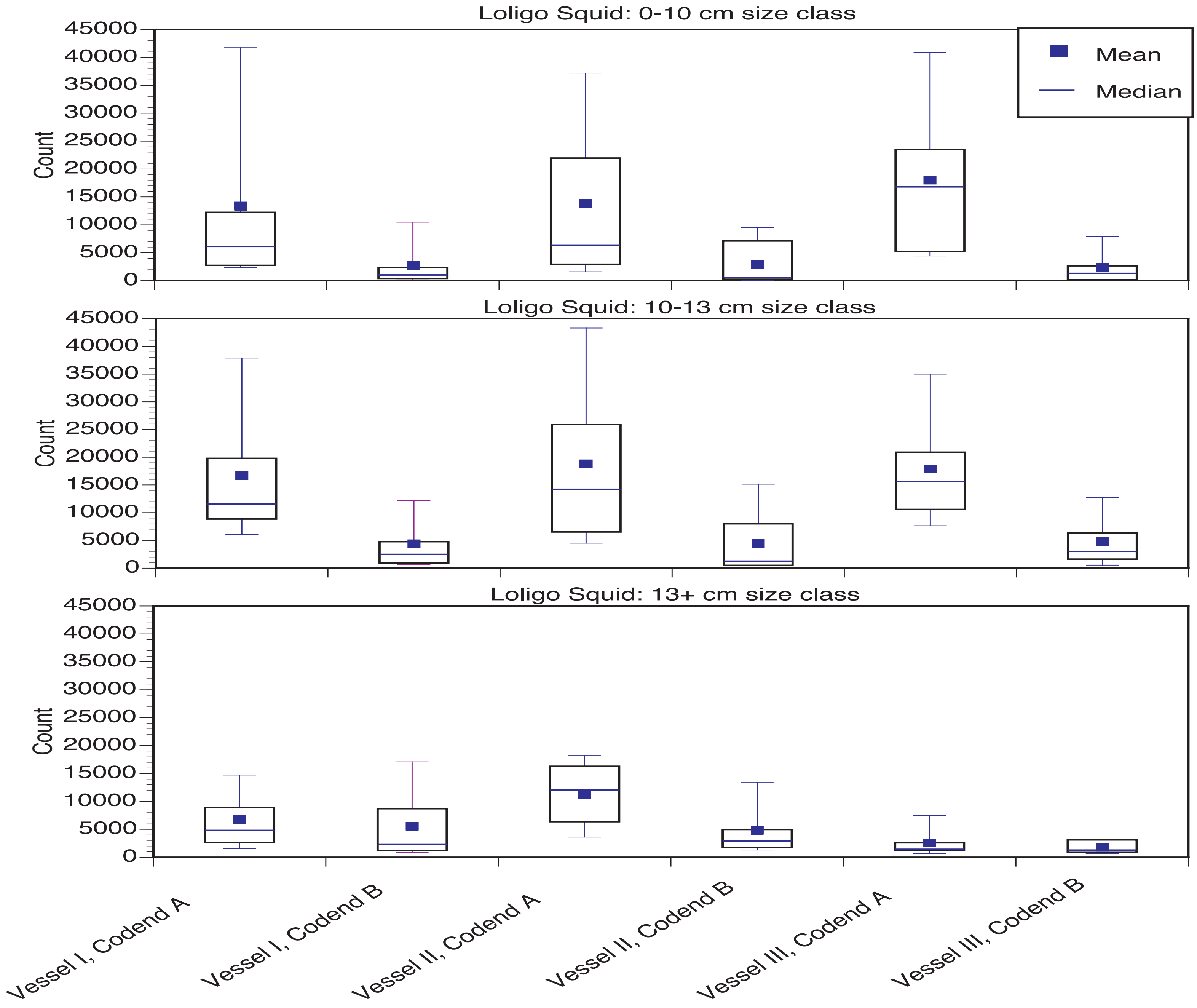
- Significantly less *Loligo* were caught by larger mesh by weight and #s (p values 0.001-0.005) regardless of which vessel fished the exp. codend

Figure 4. Box and whisker plot of *Loligo* catch with control (A) and experimental (B) codends on three participating vessels. The box encompasses the interquartile range, with the median as the central line, the mean as the ■ and the whiskers as the range.



Results

- *Loligo* squid caught in three size classes with experimental codend
  - Significantly fewer small and medium-sized squid were caught by larger mesh codend (p values 0.001-0.019) regardless of boat towed the exp. codend
  - Large squid >13 cm results were inconsistent and tended to escape capture in the experimental codend but the difference in capture efficiency was small only one vessel



Loligo Squid: 0-10 cm size class
Mean
Median
Count
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Loligo Squid: 10-13 cm size class
Loligo Squid: 13+ cm size class
Vessel I, Codend A
Vessel I, Codend B
Vessel II, Codend A
Vessel II, Codend B
Vessel III, Codend A
Vessel III, Codend B

Results

- *Loligo* squid size frequencies
  - The percentiles (25th, 50th, and 75th), mean size, and the interquartile range and range were significantly larger in tows using the exp. codend in comparison to tows using 1.875" codend (P value <0.001)
    - Significant cruise effect size of fish available changed from one cruise to the next
- Statistical Power-calculated *B* or 1- *B*
  - Likelihood of incorrectly falsifying a null hypothesis was low for nearly all reported significant effects

Conclusions

- Large mesh codend (2.5") resulted in greatly reduced capture of squid by weight and number
  - Difference was dominated by catch of squid <13 cm
  - Desired size range for market is 10-13 cm
  - Catch of large squid (>13 cm) was reduced somewhat but the differences were small
- The 2.5" codend did not differ significantly from standard catch by weight or number for any other investigated species

Conclusions

- **Global median catch calculated using all tows taken in all four field programs for each of two codend mesh sizes tested**
  - **1.875" mesh codend caught 17,059 kg/tow of squid (>10 cm)**
  - **Using 2.5" mesh catch was 4,45 kg/tow**
    - **Decrease in catch of 73.9%**

Acknowledgements

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