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Time of day affects *squid* catch in the U.S. *Illex illecebrosus* squid fishery

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ABSTRACT

A mid-water otter trawl fishery targeting *Illex illecebrosus* operates in the northwestern Atlantic Ocean. The majority of *I. illecebrosus* are captured during mid-June to early September. Diel migratory behavior limits the fishery to daylight hours, but does the time-of-day affect catch? *Illex illecebrosus* were collected from each tow from a subset of the trawler fleet fishing on the outer continental shelf of the Mid-Atlantic Bight over the fishing season to determine the influence of time-of-day on catch. The male-to-female ratio was not influenced by time-of-day of capture. The size–frequency distribution of *I. illecebrosus* varied between tows within the same day of capture. Time-of-day of capture influenced average weight and, to a lesser degree, mantle length. Shorter and lighter squid were caught in the middle of the day. Larger and heavier squid were caught during the morning and afternoon. Data collection on commercial fishing vessels required that squid be frozen onboard, thawed onshore, and then weighed and measured. Differences between fresh and frozen squid were significant, but small, which permitted combining fresh and frozen measurements from different boats to track temporal and spatial trends in squid size. As time-of-day differences in catch were significant, obtaining unbiased size data from fishing vessel-based reports requires that samples be collected from the morning, afternoon, and evening tows during the trip.

1. Introduction

Diel differences in the catchability of commercial and recreational fish species are well known (e.g., Petrakis et al., 2001; Vašek et al., 2009; Bower et al., 2017; Orbesen et al., 2017). Presumably, such behavior should impact the catch characteristics during the time of availability to the gear as well, as animals of different sizes and sexes may change depths at different speeds and times. That likelihood has been much less studied (Nowara and Walker, 1998; Bradburn and Keller, 2005; Jacobson et al., 2015). Squid are notorious diel migrators (Watanabe et al., 2006; Katugin and Zuev, 2007; Shea and Vecchione, 2010; Jacobson et al., 2015; Judkins and Vecchione, 2020). Among these squid species is *Illex illecebrosus* (Brodziak and Hendrickson, 1998). The U.S. *I. illecebrosus* fishery operates in the northwestern Atlantic Ocean and utilizes several types of mid-water otter trawl gear with codend mesh sizes of 47.6 mm or greater (Brodziak and Hendrickson, 1998; Dawe and Hendrickson, 1998; NEFSC, 1999). Most *I. illecebrosus* are caught during mid-June to early September (NEFSC, 1999; Powell et al., 2005).

Illex illecebrosus squid are short-lived with a life span of not more than one year (Dawe and Beck, 1997; NEFSC, 1999; Hendrickson, 2004). Real-time management, in which fishing vessel-based data are collected during the fishing season to set regulatory limits, offers an intriguing option for this species, as the current management system typically requires several years to set a catch quota. Some squid fisheries utilize real-time management (Agnew et al., 1998; Basson et al., 1996; Rosenberg et al., 1990), but this management technique has not been applied to U.S. squid fisheries, although it has been considered (Johnson and van Densen, 2007; Johnson, 2010). In order to manage squid on a real-time basis, catch and effort data must be collected from the fishing fleet during the course of the fishing season. An economic approach to data collection would rely on the fishing fleet to report catch and effort data throughout the season (Powell et al., 2003a,b). The dynamics of catch during the fishing day consequently are important, and in particular, the extent to which the diel migration influences availability during the daylight hours when the fishery is prosecuted.

This study was undertaken to evaluate the degree to which the characteristics of *Illex illecebrosus* catch vary during the fishing day, which can inform sampling protocols so that catch data are reported in an unbiased way across the daylight hours. We hypothesized that the diel migratory behavior might be differentially exhibited by squid of different sex and size and, consequently, sampling bias, targeting the first catch of the day for

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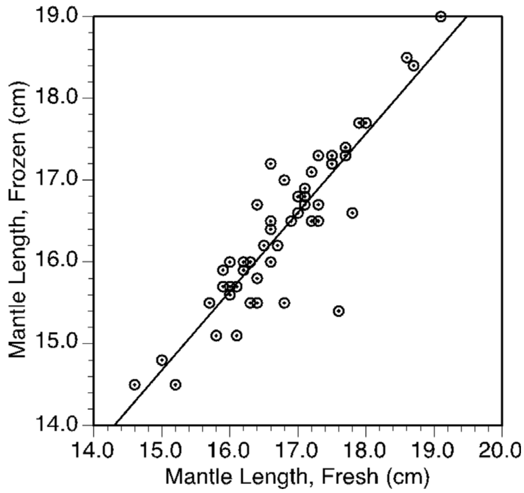

Fig. 1. The relationship between the mantle length of fresh and that of frozen squid. The conversion for mantle length was: Thawed frozen = 0.96 Fresh + 0.22 ($r^2 = 0.80$).

example, might markedly skew fishing vessel-based reports of catch. We also hypothesized that expected differences in catch characteristics might provide an improved understanding of diel migratory behavior, as ontogeny is known to influence this behavior in some squid species (Nowara and Walker, 1998; Judkins and Vecchione, 2020).

2. Methods

2.1. Data collection

Four fishing vessels participated in the study during the 2001 *Illex illecebrosus* fishing season. Two were large freezer trawlers, 45 m long originating from Rhode Island. The other two fishing vessels were a relatively large (42 m long) and a relatively small (27 m long) RSW (refrigerated seawater) trawler operating from the port of Cape May, NJ. These two ports account for most *I. illecebrosus* landings. The U.S. *I. illecebrosus* fishery is prosecuted in the Mid-Atlantic Bight near the edge of the continental shelf at varying depths with codend mesh sizes of ≥47.6 mm (Powell et al., 2003a, 2005). The areas fished during the time frame of the study are provided in Powell et al. (2003b, 2005) – Fig. 1 in each case).

This study occurred from June through early September with the fishery occurring at varied depths on the outer continental shelf. Data were collected under normal fishing operations by onboard observers. For each tow, fishermen recorded the number of pounds of *I. illecebrosus* squid kept and discarded, position at the start and termination of the tow, and the time the net was set and hauled back. Fifty *I. illecebrosus* squid were randomly collected from each tow, the dorsal mantle lengths measured in centimeters to 0.5 cm, the total body weight measured to 1 g, and the sex (male, female, undetermined) recorded. On some trips, a motion compensated scale was used to weigh the squid at sea. In other cases, squid were brought back to the laboratory frozen, then thawed, measured, weighed, and sexed. Details of the size and weight trends for the period of interest have been provided by Powell et al. (2005).

To determine whether freezing impacted the mantle lengths and weights of the squid, 50 fresh *I. illecebrosus* were measured and weighed and then individually labeled and frozen onboard the vessel. The squid were then thawed in the laboratory, measured, and weighed again.

Table 1
Descriptive statistics for the five *Illex illecebrosus* trips taken during June through September, 2001. Boat represents the four fishing vessels participating in the study. Boats B and C are freezer trawlers. Boats A and D are refrigerated seawater (RSW) boats.

Trip date	Boats	Total number of tows	Total number of tows with measured lengths and/or weights
June 14–20	B	17	12
July 2–5	D	6	5
July 9–21	B	33	32
July 23–27	A	8	8
August 22-September 5	C	37	37
Total		101	94

2.2. Statistical analysis

To evaluate time-of-day effects on the size–frequency of the squid captured, tows were assigned to three categories based on haulback times: Time 1, 7:00–11:59; Time 2, 12:00–16:59; and Time 3, 17:00–21:59. The 10th, 25th, 50th, 75th, and 90th percentiles of mantle length were used to describe the size–frequency.

ANOVAs were run using ranked raw variables with main effects that defined fishing decisions including tow and net haulback time, day of the year, and sex, depending upon the purpose of the analysis. In most cases multiple vessels fished on any given day. In each case, all vessels fishing on a given day were included in the day-of-year effect. Significant differences identified were further investigated using *a posteriori* least squares means tests. Probabilities were calculated using an exact binomial test or the normal approximation for large sample sizes, depending upon need (Conover, 1980).

3. Results

3.1. Fishery description

Illex illecebrosus were sampled on 32 days during June through early September from five fishing trips totaling 44 days at sea. A total of 101 tows were taken during daylight hours (dawn to dusk). The number of tows per day in which squid were measured ranged from 2 to 5. *Illex illecebrosus* were measured from 94 of those tows and weighed from a subset of those tows (Table 1). A total of 5135 squid were measured, 2815 squid weighed, and 4491 squid sexed (Table 2). Of the sexed *I. illecebrosus*, 2394 were males and 2097 were females. More males than females were caught on 24 of the 32 days in which tows were conducted, an unlikely event by chance given a 50:50 expectation (binomial test, $P < 0.005$).

3.2. Fresh vs. frozen

Mean mantle length of fresh and frozen squid was 16.8 cm (±0.90) and 16.4 cm (±0.97), respectively (Fig. 1). Mean total body weight of fresh and frozen squid was 77.7 g (±12.43) and 73.52 g (±11.99), respectively (Fig. 2). The mean deviation between fresh and frozen squid was 0.39 cm (±0.434) for mantle length and 4.18 g (±2.389) for body weight. In no case was either deviation biased with respect to squid size (length or weight). The conversion for mantle length was: Thawed frozen = 0.96 Fresh + 0.22 ($r^2 = 0.80$). The conversion for body weight was: Thawed frozen = 0.95 Fresh - 0.034 ($r^2 = 0.96$).

Table 2
Results of ANOVA tests of mantle length, weight, and mantle length-to-weight ratio by tow and sex by year–day. Year–day represents the date the tows were taken. Per-day statistics included all vessels reporting on that day. X indicates an interaction term. Results are presented as P < given *P*-value. NS indicates no significance at $\alpha = 0.05$. - indicates no data available.

Year–Day	TOW			SEX			TOWxSEX		
	Length	Weight	Ratio	Length	Weight	Ratio	Length	Weight	Ratio
166	0.0001	0.0001	0.0001	0.0001	0.0188	NS	NS	NS	NS
168	NS	0.0005	0.0001	0.0001	0.0001	0.0007	NS	NS	NS
184	0.0001	–	–	0.0010	NS	NS	NS	–	–
185	NS	NS	NS	0.0001	NS	NS	NS	NS	NS
192	0.0017	–	–	0.0001	–	–	NS	–	–
193	0.0014	–	–	0.0001	0.0501	NS	0.0125	–	–
194	0.0115	–	–	NS	NS	NS	NS	–	–
195	NS	–	–	0.0001	NS	NS	NS	–	–
196	0.0003	–	–	0.0001	–	–	0.0196	–	–
197	NS	–	–	0.0038	NS	NS	NS	–	–
198	NS	–	–	0.0002	NS	NS	NS	–	–
199	0.0001	–	–	0.0001	NS	NS	NS	–	–
200	0.0001	–	–	NS	NS	NS	NS	–	–
201	0.0001	–	–	NS	NS	NS	NS	–	–
235	NS	0.0265	0.0050	NS	NS	NS	0.0043	0.0398	0.0497
236	0.0127	NS	NS	0.0007	NS	NS	NS	NS	NS
237	0.0002	0.0022	0.0031	0.0016	0.0384	NS	NS	NS	NS
238	0.0291	NS	NS	0.0137	NS	NS	NS	NS	NS
239	NS	0.0001	0.0001	0.0001	0.0030	NS	NS	NS	NS
240	NS	NS	NS	NS	NS	NS	NS	NS	NS
241	NS	NS	NS	NS	NS	NS	NS	NS	NS
242	0.0112	0.0085	0.0160	NS	NS	NS	NS	NS	NS
243	NS	NS	0.0320	0.0002	NS	NS	NS	NS	NS
244	NS	NS	NS	0.0038	NS	NS	NS	0.0400	NS
245	0.0123	0.0030	0.0058	0.0001	0.0159	NS	NS	NS	NS
246	0.0001	0.0001	0.0001	0.0067	–	NS	NS	NS	NS
247	0.0031	0.0001	0.0001	0.0009	0.0200	NS	NS	NS	NS
205	–	–	–	NS	NS	NS	–	–	–
206	–	–	–	NS	NS	NS	–	–	–
207	–	–	–	NS	NS	NS	–	–	–

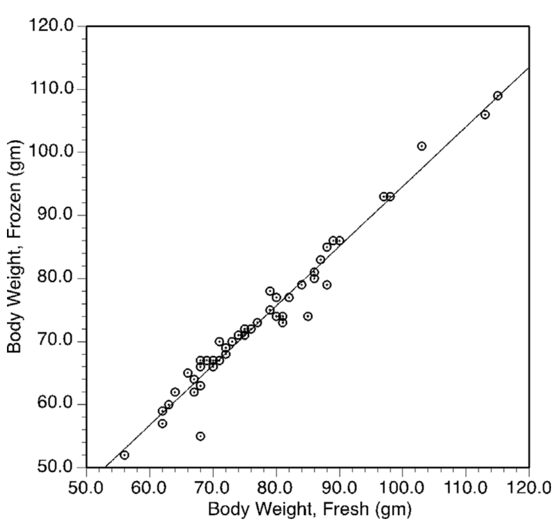

Fig. 2. The relationship between the weight of fresh and that of frozen squid. The conversion for body weight was: Thawed frozen = 0.95 Fresh - 0.034 ($r^2 = 0.96$).

3.3. Length–weight

Mantle length, total body weight, and the length-to-weight ratio varied significantly between tows within the date of capture; such events occurred routinely throughout the fishing season (Table 2). Mantle lengths differed significantly at $\alpha = 0.05$ in 16 of 27 cases, an occurrence rate much more frequent than expected by chance (exact binomial test at $\alpha = 0.05$; $P < 0.0001$). Both the body weight and mantle length-to-weight ratio were also often significantly different between tows within the date of capture. Significant differences occurred in 9 of the 16 cases, an occurrence rate much more frequent than expected by chance (exact binomial test at $\alpha = 0.05$; $P < 0.0001$). Therefore, tow-to-tow differences in mantle length, body weight, and mantle length-to-weight ratio were the norm rather than the exception.

3.4. Male–Female Comparisons

Although more males were caught than females on most days, the male/female ratio rarely varied among tows on the same day; significant differences occurred in only 3 of 27 days, an occurrence rate not different from chance (exact binomial test at $\alpha =$ 0.05). In general, mantle lengths of males and females differed significantly on most days throughout the fishing season (Table 2). In contrast, total body weight between males and females differed less often (7 cases out of 24), although this frequency was still much more often than expected by chance (exact binomial test at $\alpha = 0.05$; $P = 0.0001$). The interaction term with tow was rarely significant indicating that the dimorphic size distribution commonly observed in *Illex* squid species, the female being larger (Gonzalez and Guerra, 1996; Hendrickson and Holmes, 2004; Cereola et al. 2006; Petric et al., 2010), was similar in all tows of the day on most days (Table 2. Thus, the routinely observed significant differences in mantle length between tows could not be attributed to variation in male/female ratio between tows.

3.5. Time-of-day effects

Tow-to-tow differences in length and weight were further investigated by examining whether the time-of-day of the tow had an effect upon the sex ratio, mantle length, and body weight of *Illex* squid caught. Sex ratio varied little throughout the day with males more common than females (female:male 48:52 (morning),

Table 3
Results of ANOVA tests for all squid and for the catch allocated to a series of size categories based on percentiles: the largest 10% (90th percentile), the largest 25% (75th percentile), the smallest 25% (25th percentile), and the smallest 10% (10th percentile) with respect to mantle length and body weight. Year–day represents the date the tows were made. X indicates an interaction term. Results are presented as P < given P-value. NS indicates no significance at $\alpha = 0.05$. – indicates no data available. The time periods for the analysis were broken down into those tows with haulback times that fell into three categories: morning (Time 1): 7:00–11:59, afternoon (Time 2): 12:00–16:59, and evening (Time 3): 17:00–21:59.

Length					
	All squid	90th percentile	75th percentile	25th percentile	10th percentile
Time	0.0001	NS	0.0430	0.0017	0.0005
Day	0.0001	0.0001	0.0001	0.0001	0.0001
Time x Year day	0.0001	NS	NS	0.0016	0.0007
Weight					
	All squid	90th percentile	75th percentile	25th percentile	10th percentile
Time	0.0001	0.0027	0.0001	0.0014	NS
Year Day	0.0001	0.0001	0.0001	0.0001	0.0001
Time x Year Day	0.0001	0.0333	0.0002	0.0031	NS

47:53 (afternoon), 44:56 (evening). Males were slightly more common in evening catches than in morning catches (P = 0.019), whereas the afternoon tows did not differ significantly from morning or evening tows.

In contrast, time of net haulback, year–day, and the interaction of year–day and time of net haulback had highly significant effects upon squid mantle length (each P < 0.0001), body weight (each P < 0.0001), and mantle length-to-weight ratio (each P < 0.0001) (Table 3). The mantle lengths of squid caught in the morning were significantly longer than those caught in the afternoon (P = 0.0009), but not in the evening. The mantle lengths of squid caught in the afternoon were significantly shorter than those caught in the evening (P = 0.0001) (Table 4). Overall, *Illex* squid tended to be smaller in the afternoon (mean mantle length 16.42 cm) than during the morning (mean mantle length 16.60 cm) and the evening (mean mantle length 16.65 cm). Similarly, the body weight of squid caught during the morning tows was significantly greater than the body weight of squid caught in the afternoon (P = 0.0001). The heaviest squid were caught in the evening, significantly heavier than squid caught in the morning (P = 0.0113) or the afternoon (P = 0.0001) (Table 4). In summary, shorter and smaller (less heavy) squid tended to be caught in the afternoon. Longer and heavier squid were caught in the morning (mean 83.45 g), with the heaviest squid caught in the evening.

3.6. Time-of-day effects by size class

We examined the size–frequency distribution in more detail by breaking the catch into squid above the 90th and 75th percentiles in size and below the 25th and 10th percentiles in size. For mantle length, time-of-day had a significant influence in three of four size categories (Table 3). Only the largest squid (those above the 90th percentile in mantle length) were not influenced by time-of-day. *A posteriori* least squares means tests confirmed that for the three size categories differing significantly, morning and evening never differed significantly in the size of squid caught based on mantle length, whereas afternoon catches were consistently significantly different (Table 5).

For body weight, time-of-day had a significant influence in three of four size categories (Table 3). Only the smallest squid (below the 10th percentile in body weight) were not influenced by time-of-day. *A posteriori* least squares means tests showed that for the three size categories that differed significantly, morning, afternoon, and evening, often were unique, each differing from the other two (Table 5). In these cases, the largest squid were always caught in the evening and the smallest squid in the afternoon (Table 4). The data show that the variation in mantle length and body weight between the morning, afternoon, and evening are produced by a general shift in the size–frequency distribution.

4. Discussion

The mean deviation between fresh and thawed frozen squid was 0.39 cm for mantle length and 4.18 g for body weight, with thawed frozen squid tending to weigh less. Both differences, in mantle length and body weight, were small. Few comparisons of fresh and thawed frozen wet weights are reported, but those that are reported are consistent in that thawed frozen weights are modestly lower than fresh weights, probably due to dewatering upon thawing (Otwell and Giddings, 1980). Ogle (2009) reviewed a number of finfish studies and found that thawed frozen weights were lower than fresh weights, but that the difference was rarely more than 5%. Bradbury et al. (2005) examined Manila clams (*Ruditapes philippinarum*) and found similar results. Comparisons of length changes are rarer. Ogle (2009) reviewed a range of fish studies and found that length never varied substantially between fresh and thawed frozen fish. Morson et al. (2012) examined fresh and frozen summer flounder (*Paralichthys dentatus*) racks with similar conclusions; thawed frozen specimens lost a very modest amount of length, inconsequential for most purposes. In this study, the differences in length and weight of fresh versus frozen were small and easily corrected for using regression equations with high regression coefficients (Figs. 1 and 2).

The proportion of males and females in the catch was little influenced by the time-of-day of capture. Males were consistently slightly more common than females: a nearly constant ratio of 53:47 males:females. The few differences observed were in July. Interestingly, in 1983 and 1984 off the Nova Scotian shelf, Arkhipkin and Fetisov (2000) found that females dominated catches, especially in July. On the other hand, Amaratunga et al. (1978) found that *Illex illecebrosus* collected from the Scotian Shelf had a sex ratio of 57:43 with males dominating the samples until late in the season and Arkhipkin (2000) observed males to be more common in instances when the sex ratio varied distinctly from 1:1 for *Illex argentinus*, Similar findings of a sex ratio near 1:1 with a slight overrepresentation for males or females are reported by Arvanitidis et al. (2002), Ceriola et al. (2006), and Petric et al. (2010). Thus, the slight over-representation of males in this study is not an unusual observation for *Illex* squid

The mantle lengths of males and females greatly varied within the date of capture with females being larger. Variation over the summer months is not surprising as *I. illecebrosus* grow rapidly over this time frame (Powell et al., 2005). Powell et al. (2005) noted that squid tended to be smaller and lighter in 2001 than in the five preceding years and particularly 1998–1999 and this was particularly true for weight. Not surprisingly, total body weight of males and females did not appear to vary as much within the date of capture, although females were usually heavier. Weights fell considerably below those observed by Lang and Johnson (1981) who noted that on average female *Illex* squid were larger and heavier than males: mean mantle length was 19.3 cm for males and 22.3 cm for females and mean total weight was 164.2 g for males and 245.8 g for females in the Mid-Atlantic region. Squire (1967) reported that female *I. illecebrosus* captured off Newfoundland were usually larger. Amaratunga et al. (1978) found that males tended to be heavier than females for a given mantle length. Dawe and Beck (1997) reported that mantle lengths of individuals of the same age of each sex varied by more than 10 cm for squid captured off of Newfoundland. Dawe and Beck (1997) also found that females tended to grow faster than males.

Table 4
Mean mantle lengths (cm) and body weights (g) and standard error for all squid and for the catch allocated to a series of size categories based on percentiles: the largest 10% (90th percentile), the largest 25% (75th percentile), the smallest 25% (25th percentile), and the smallest 10% (10th percentile) with respect to mantle length and body weight. The time periods for the analysis were broken down into those tows with haulback times that fell into three categories: morning (Time 1): 7:00–11:59, afternoon (Time 2): 12:00–16:59, and evening (Time 3): 17:00–21:59. A total of 5135 squid were measured, 2815 squid weighed, and 4491 squid sexed.

Length	All squid		90th percentile		75th percentile		25th percentile		10th percentile	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
Time 1	16.60	0.03	19.07	0.11	18.22	0.06	15.40	0.04	15.11	0.06
Time 2	16.42	0.03	18.77	0.28	17.78	0.15	14.97	0.09	14.44	0.16
Time 3	16.65	0.03	19.10	0.13	18.21	0.08	15.45	0.05	15.02	0.09
Weight	All squid		90th percentile		75th percentile		25th percentile		10th percentile	
	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE	Avg.	SE
Time 1	83.45	0.56	118.31	1.90	104.87	1.08	63.13	0.45	60.95	0.66
Time 2	73.97	1.32	106.47	4.73	93.55	2.67	60.20	0.97	55.98	1.51
Time 3	85.33	0.69	126.03	2.48	108.99	1.43	67.58	0.56	61.61	0.90

Table 5
Least squares means results for ANOVA analyses reported in Table 3. Results are presented as P < given P-value. NS indicates no significance at $\alpha = 0.05$.

Mantle length			Body weight		
10th percentile size fraction			10th percentile size fraction		
	Time 2	Time 3		Time 2	Time 3
Time 1	0.0063	NS	Time 1	NS	NS
Time 2	–	0.0153	Time 2	–	NS
25th percentile size fraction			25th percentile size fraction		
	Time 2	Time 3		Time 2	Time 3
Time 1	0.0136	NS	Time 1	0.0103	0.0004
Time 2	–	0.0012	Time 2	–	0.0001
75th percentile size fraction			75th percentile size fraction		
	Time 2	Time 3		Time 2	Time 3
Time 1	0.0011	NS	Time 1	0.0001	NS
Time 2	–	0.0119	Time 2	–	0.0001
90th percentile size fraction			90th percentile size fraction		
	Time 2	Time 3		Time 2	Time 3
Time 1	NS	NS	Time 1	0.0252	0.0249
Time 2	–	NS	Time 2	–	0.0006

Change in capture rate at various times of day is a well-known phenomenon for many marine species (e.g., Buckel et al., 1999; Gillis, 1999; Bullough et al., 2007; Ryer et al., 2010). Day–night vertical migration is well described for many squid species (Lange and Sissenwine, 1980; Lange and Waring, 1992; Hendrickson and Holmes, 2004). We observed a high degree of variation in mantle length, body weight, and length-to-weight ratio between tows within the fishing day. This variation occurred throughout the fishing season in our study (June 14–September 5). Overall, *Illex* squid tended to be smaller in the afternoon than during the morning or the evening. Squid body weight varied to an even greater degree than mantle length between the morning, afternoon and evening catches. That is, the variation in weight was not explained solely by variation in mantle length. The squid tended to be much lighter in the afternoon then during the morning and distinctly heavier in the evening.

Brodziak and Hendrickson (1998) found that pre-recruit (juvenile squid) (≤10 cm mantle length) catches were highest during the day (8:00–15:59) and recruit catches (adult squid) (>10 cm mantle length) peaked during dawn (4:00–7:59) and dusk (16:00–19:59). Our catches were all adult squid but the trends in size are consistent with Brodziak and Hendrickson (1998). The mantle lengths of squid in the 10th, 25th, 75th, and 90th percentile groups did not differ significantly in the morning and evening catches. This was not the case for body weight. This reinforces the inference that the heavier squid caught in the evening did not simply represent a return of the morning size–frequency. Rather, these squid were heavier for a given mantle length. Nor does variation in the male:female ratio explain the difference in body weights. This ratio varied little and males, routinely smaller than the females, were nonetheless slightly more common in the evening catches that yielded on the average the heaviest squid.

An explanation for the observed differences in mantle length and body weight between morning, afternoon, and evening catches remains unavailable, but the consistent presence of these differences suggests that important within-population differences in spatial distribution exist during the day–night vertical migration. Unquestionably, larger squid spend more time near the bottom than smaller squid, and the heaviest of these larger squid spend even more time there. Presumably, such differences evince variations in feeding strategy, which, are known to vary with the size of the squid (e.g., *Illex argentinus*, Ivanovic and Brunetti, 1994).

Large changes in squid abundance occur between years as a function of climate cycles and other environmental changes (Bazzino et al., 2005; Frisk et al., 2011; Nye et al., 2014). Implementation of a real-time management initiative would require tracking catch metrics on a daily basis. For this purpose, squid can be frozen onboard the vessel, thawed and then weighed and lengths measured because of the small bias in the weight and length measurements that exists between fresh and frozen squid. These biases can be readily corrected. The size–frequency distribution of *Illex* squid varied between tows within the same day of capture, however, whether measured by mantle length or body weight. Therefore, obtaining data on size from fishing vessel catches requires that samples be collected from more than one period in the day or be randomized in time across days. Relative stability in the day-to-day differences in the catches with respect to time-of-day makes this latter option feasible.

CRediT authorship contribution statement

Eleanor A. Bochenek: Conceptualization, Methodology, Investigation, Visualization, Writing - review & editing. **Eric N. Powell:** Conceptualization, Methodology, Investigation, Software, Funding acquisition, Supervision, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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