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Short-term post-release mortality of skates (family Rajidae) discarded in a western North Atlantic commercial otter trawl fishery

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ABSTRACT

Due to market and regulatory factors, Rajidae skates are routinely discarded by commercial otter trawlers in the western North Atlantic. Accounting for post-release mortality is therefore essential to total fishing mortality estimates, stock status and management of this group of fishes. However, despite a presumed species-specific range in tolerance, few studies have investigated the short-term post-release mortality among skates indigenous to the western North Atlantic following capture by mobile fishing gears, and never in the Gulf of Maine. This study addresses this shortfall for the prohibited thorny skate, *Amblyraja radiate* and smooth skate, *Malacoraja senta*, and the targeted winter skate, *Leucoraja ocellata*, and little skate, *Leucoraja erinacea*. Of 1288 skates evaluated, negligible immediate mortality was observed at the time of capture, even in relation to the largest catches and/or most prolonged tows. However, injury frequency was moderate, with highest levels in the smooth (60%) and thorny (52%) skates. Aside from the smooth skate (59%), 72 h mortality rates were low overall (19% across all species when accounting tow durations indicative of the fishery), with the winter skate (8%) exhibiting the lowest levels. Logistic regression modeling revealed tow duration as the most universal predictor of condition and 72 h mortality, while catch biomass, sex, temperature changes, and animal size also held influence in certain species. Although in general the studied species appear more resilient to trawl capture and handling than previously estimated, interspecific differences must be accounted for when managing this group.

1. Introduction

Post-release (P-R) mortality estimates for discarded fish are highly important toward, among other management goals, calculating total fishing mortality and biologically acceptable catch limits (Alverson, 1999; Davis, 2002). While complex due to various influencing factors (Davis, 2002) and species differences, pinpointing the specific aspects of the capture and handling process most impactful on P-R mortality can also be exploited to help illuminate best practice scenarios to reduce that mortality (e.g., Parker et al., 2003; Cooke and Suski, 2005).

Skates, like other elasmobranchs, display a K-selected life history (i.e., long lived, late sexual maturation, low fecundity), which make them vulnerable to fishing pressures (e.g., Waring, 1984; Hoening and Gruber, 1990; Sulikowski et al., 2003). These life history characteristics, coupled with global increases in skate landings (e.g., Dulvy et al., 2000; Sulikowski et al., 2005) and high discard rates have led to increasing management and conservation concerns and the need for estimates of fishing mortality. However, only a handful of studies to date have investigated discard mortality rates in skates in general (e.g., Benoît, 2006; Enever et al., 2009; Benoît et al., 2010a), all of which focused on demersal mobile fishing gears. Based on the collective results of these studies, skates suffer moderate P-R mortality (i.e., majority = 40–50%), with factors that influence risk of crushing/compaction and resulting physical trauma (e.g., tow duration, species, animal size, and total catch biomass) appearing to exert the most influence.

The Northeast Skate Complex (NESC) comprises seven species, five of which occur in the Gulf of Maine (GOM) (NEFMC, 2003), where otter trawl is the primary gear responsible for the capture and discard of skates (Sosebee, 1998; NEFMC, 2003, 2011). P-R mortality estimates of trawled skates under a wide range of true commercial conditions are vital toward, among other endpoints, estimating exploitation rates and establishing total allowable landings (NEFMC, 2005, 2011). It is also an important management goal to elucidate interspecific differences regarding both the rate and factors that influence P-R mortality in this complex.

Although a few studies have evaluated discard mortality in trawled NESC species within Canadian waters, sample sizes were either small for certain species (Benoît, 2006), or mortality rates

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were not distinguished by species (Benoît et al., 2010b). Moreover, intraspecific morphological and biological disparities in NESC species between Canadian and USA stocks (Swain et al., 2006) emphasizes the need for P-R mortality investigations specific to the GOM. Thus, the objective of the present study was to investigate the interspecific acute condition and short-term P-R mortality in four NESC skate species under standard commercial otter trawl conditions in the GOM. The little (*Leucoraja erinacea*) and winter (*Leucoraja ocellata*) skates are the subject of directed fisheries, whereas the thorny (*Amblyraja radiata*) and smooth skates (*Malacoraja senta*) are prohibited from commercial retention due to overfished stock conditions. A secondary goal of this work was to identify the biological and/or physical factors with the most influence on condition and P-R mortality.

2. Materials and methods

2.1. Study overview

Discard mortality trials were conducted in the GOM aboard two commercial trawlers (Fishing Vessels; F/Vs "Mystique Lady" and "Lady Victoria"), of comparable size (~13 m) and gear specifications. The trawls had an 11 m long groundgear and an 18.5 m long headline, and were constructed with 152 mm mesh size in the trawl body and 165 mm diamond mesh in the codend. The groundgear was outfitted with a 30.5 cm rockhopper and 20.4 cm rubber disks. Research trips (2009–2011) took place annually from April–July, with the exception of 2011, where fishing was only conducted in June and during the fall (October–December), when temperature regimes were comparable to the spring (April–May) in previous field seasons. All work was conducted in coastal and offshore waters off northern Massachusetts and southern New Hampshire, USA (boundaries of quadrilateral study area = upper left–right (42°53′N 70°45′W–42°56′N 70°24′W); lower left–right (42°22′N 70°25′W–42°24′N 70°20′W), exclusively on sand and/or mud substrate and a depth range of 15.8–75 m. Ranges for bottom seawater temperatures, air temperatures, and the gradient between the two were (3.47–9.6 °C), (7.0–33.0 °C), and (−1.7–28.6 °C), respectively.

2.2. Fishing research protocols

A total of 71 tows were conducted between the two vessels, partially based on fishing protocols described in Mandelman and Farrington (2007). During each research trip tows of differing durations ("control" (15–20 min, refer to Section 2.3); moderate (90–120 min); and extended (180–240 min)) were randomly conducted between 0600 and 1300 h. Similar to past studies (e.g., Neilson et al., 1989), the precise time-point skates entered the trawl net during the course of a tow was indeterminable, and tow durations therefore represented maximum codend residence times (i.e., maximum period of gear exposure and capture stress). Hobo temperature loggers (Onset Computer Corporation, Bourne, MA, USA) were affixed to the trawl net and boat deck to evaluate real-time seawater and air temperature profiles experienced during the process of capture and catch handling, respectively. Catch (codend) biomass (i.e., tow weight) for each tow was estimated (lbs) by the collaborating commercial fisherman (presented here in kg; range = ~34–4990 kg), but binned into broader categories (small: <318 kg; moderate: ≥318 kg, ≤1270 kg; and large catch: >1270 kg) for analysis.

2.3. Condition index and mortality investigations

Once deposited on deck, the target and non-target catch was sorted by the fishermen as would occur under normal circumstances. Given, however, the previously noted indeterminate time of entry for skates into the net during the course of trawling, and the multiple additional interacting factors at play, the condition of skates from a given tow at the point of landing on deck was assumed to vary considerably animal-to-animal. To avoid misleading results from adding an additional layer, time on deck (i.e., air exposure) was therefore standardized (~10 min) for all skates in the study. Readers are referred to a recent study on air exposure and skates for a more controlled investigation of this factor in the little skate (Cicia et al., 2012).

Approximately 10 min after haul-back, any immediate fatalities were recorded, while randomly selected live skates were transferred to circular deck tanks (dimension: 61 cm in depth; 121.9 cm diameter; held at consistent densities: 10–15 animals/tank), which were continuously flushed with surface sea water (range = 9–15 °C). Because surface seawater temperature (SST) varied as a function of month, which was accounted for as a predictor variable in the logistic regression models, SST was not included as a factor in study analyses. As specimens were traversing the surface stratum temperatures during net haul-back and initial deployment of pens, it was decided to utilize ambient surface sea water and not to chill deck tanks. Additionally, to more closely reflect typical commercial handling producers, random subsamples of skates were "picked" with a deck gaff, a hand-held fish-sorting tool utilized to maneuver catch, which is known to inflict puncture wounds.

Following the transfer to deck tanks, each skate was removed (60–90 s) to record species of skate, sex, total length (TL, cm), condition (scale 1–3), and subsequently each individual was coded in the lateral tail region with a dart tag (Floy Tag & Mfg. Inc., Seattle, WA, USA). Viability/condition categories were partially based on indices previously described (e.g., Neilson et al., 1989; Enever et al., 2009; Benoît et al., 2010b), with employment of the following criteria: category 1 (intact), no obvious physical trauma, vigorous; category 2 (moderate), overt minor-to-moderate hemorrhaging/trauma, diminished vigor; or category 3 (extensive), hemorrhaging, deep tissue trauma/tearing, listless or moribund (Fig. 1). As such, no "picked" skates were assigned as category 1. These categories were kept purposefully broad to reduce any inherent biases associated with the subjectivity of vitality coding and multiple research staff assigning scores.

After a short steam (~30 min after the termination of a tow), skates were transferred from the deck tanks into partially submerged net pens, and slowly lowered to the seafloor (exclusively on mud substrate to reduce the likelihood of amphipod/isopod (i.e., "sand fleas") infestation) for in situ 72 h mortality trials. To maximize surface area on the seafloor and reduce the likelihood of dislodgement, circular net pens (diameter of bottom ring = ~1.8 m; diameter of upper ring = ~1.2 m; height = ~0.9 m) were utilized, based on a modified crab pot design (Burkes Custom Metal Works, PEI, CA). Each pen was also outfitted with a special mesh bottom designed to further reduce potential for sand flea infestation. Within each pen, the total number of specimens and species make-up varied; however, biomass range was held consistent (i.e., ~15–20 smaller individuals; ~5–15 larger individuals). For logistical purposes, all skates within a pen (trial) were derived from a single tow (i.e., skates from multiple tows were never combined in a pen). Following 72 h trials, pens were retrieved to evaluate alive/dead status of skates, after which all surviving animals were released.

To account for potential additive effects on 72 h mortality from pen containment and to evaluate condition and 72 h mortality in abrupt versus the more commercially indicative (moderate and extended category) tows, eleven "control" tows (15–20 min) were conducted to obtain a subset of skates with minimal gear exposure (winter: $n = 86$; little: $n = 96$; thorny: $n = 56$). Although skates were handled gently and exposed to minimal (3–5 min) deck times to reduce handling stress prior to pen trials, specimens