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Quantification of the indirect effects of scallop dredge fisheries on a brown crab fishery

Fikret Öndes [a, b, *], Michel J. Kaiser [a], Lee G. Murray [a]

[a] School of Ocean Sciences, Bangor University, Menai Bridge, Anglesey, LL59 5AB, UK
[b] Faculty of Fisheries, Izmir Katip Celebi University, Izmir, 35580, Turkey

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ABSTRACT

This study aimed to describe the characteristics of the by-catch of *Cancer pagurus* in king scallop dredges in the Isle of Man, and to determine the damage, immediate mortality and estimated mortality during fishing seasons associated with scallop dredges. Based on dredge surveys, spatial and seasonal variations were observed, with the highest number of crabs found off the west coast of the Isle of Man in the autumn when berried females crabs were most frequently caught. In general, female crabs comprised 84% of the catch. The damage levels of crabs was high with 45% of crabs recorded as crushed or dead or with severe damage, whilst 24% of crabs exhibited missing limbs. Estimates of the potential mortality associated with scallop dredging led to a lower and upper estimate of possible crab by-catch mortality of 15t and 24t respectively which represented 3.0–4.8% of the commercial landings of brown crab for the Isle of Man. Heaviest mortalities of crabs occurred in autumn to the west of the Isle of Man when female berried crabs move offshore into deeper water. The use of a temporary and spatially restricted scallop dredging closure could provide a simple solution to mitigate additional crab mortality in the event that scallop dredging increased beyond current levels in the future.

1. Introduction

An ecosystem-based approach to fisheries management demands a clear understanding of the effects of fisheries on other components of the ecosystem in addition to the target species (Zhou et al., 2010; Link, 2002). Towed mobile bottom-fishing gears, such as scallop dredges and trawls, change the structure of benthic communities and habitats to varying extents, and can be associated with high catches of by-catch species (Jennings and Kaiser, 1998; Kaiser, 2000; Queirós et al., 2006). By-catch species that are retained in mobile gear fisheries can sustain varying levels of damage and mortality that vary among different métiers (Kaiser and Spencer, 1995; Lindeboom and de Groot, 1998; Auster and Langton, 1999; Johnson, 2002; Matsuoka, 2008). The magnitude of the physical damage exerted upon by-catch species is determined by a wide variety of fishery-specific factors (e.g. tow duration, towing speed, fishing depth, gear type, weight of the gear, gear configuration, season, habitat type, the proportion of debris [dead shells, stones], catch size, composition, body size and body morphology of species) (Hill et al., 1996; Ball et al., 2000; Bergmann and Moore, 2001; Bergmann et al., 2001; Veale et al., 2001; Brown et al., 2005; Sartor et al., 2006; Milligan et al., 2009; Policarpo, 2011). These factors affect the survivorship of the by-catch once it has been discarded which has important implications when estimating total mortality for a particular species (Hill et al., 1996; Veale et al., 2001; Policarpo, 2011).

Crustaceans are known to be sensitive to direct physical contact with scallop dredges and bottom-fishing trawls (Eleftheriou and Robertson, 1992; Kaiser and Spencer, 1995; Bradshaw et al., 2000; Veale et al., 2000) such that the survival rate of crabs with limited damage can be quite low (Stoner, 2012). Although crustaceans can repair limited amounts of damage to their carapace and can regenerate damaged or lost limbs, this requires investment of energy resources. This diversion of energy into tissue repair may reduce growth, lengthens intermoult duration, foraging ability, and protection from predators (Bennett, 1973; Juanes and Smith, 1995; Mariappan et al., 2000). Several studies have investigated the damage level and mortality of crabs in

* Corresponding author. School of Ocean Sciences, Bangor University, Menai Bridge, Anglesey, LL59 5AB, UK.
E-mail addresses: fikretegesu@gmail.com (F. Öndes), michel.kaiser@bangor.ac.uk (M.J. Kaiser), l.murray@bangor.ac.uk (L.G. Murray).

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scallop dredges (e.g. Hill et al., 1996; Jenkins et al., 2001; Veale et al., 2001). These studies reported that damage to crabs included limb loss, carapace and abdominal cracks and crushed body-parts. There may be other (internal) forms of physical damage and physiological stress that cannot be ascertained from visual assessment in the field.

Cancer pagurus (brown crab) is one of the most important commercial fishery species in England and Wales in terms of its economic value (valued at > £15M at first sale in 2011). Brown crabs co-occur in the same habitat as scallops and consume scallops damaged as a result of dredge fisheries (Jenkins et al., 2004). Therefore, it is not surprising that brown crabs have been recorded as a by-catch species in scallop dredges (Hill et al., 1996, 1999; Bradshaw et al., 2000; Veale et al., 2000; Beukers-Stewart et al., 2001; Jenkins et al., 2001; Veale et al., 2001; Montgomery, 2008) and in trawls (Duncan, 2009). Considering the area of the continental shelf swept by towed mobile fishing gear (Murray et al., 2013), there is considerable potential for interactions between these gears and brown crabs. Observations of brown crab elsewhere in the UK indicate that there is a directional reproductive migration of brown crab between offshore and inshore waters (Pearson, 1908; Edwards, 1979). As a result, scallop fisheries could be an important source of mortality for crabs at a critical time in their reproductive cycle if there is overlap between fishing activity and the distribution of crabs at that time. Thus, in the context of an ecosystem-based approach to fisheries management it is important to consider not only the effect of scallop dredging on the scallop population, but also to consider whether there are secondary effects on non-target species that may have implications for the fisheries they support.

The present study examines spatial and temporal variation in the potential interaction between scallop dredge and brown crabs in the waters around the Isle of Man. The Isle of Man provides a unique opportunity to study this issue due to the availability of fine resolution fishing effort data that enabled us to address this question with adequate resolution.

2. Materials and methods

2.1. Characteristics of the scallop fisheries

The fishing season for king scallops in Manx waters occurs between 1st of November and 31st of May. All vessels (irrespective of size) fishing in the scallop fishery within the territorial waters of the Isle of Man must be fitted with a vessel monitoring system (VMS). In this study, this information is used together with direct seasonal observations of crab by-catch to assess the potential impact of the scallop fishery on the brown crab fishery around the Isle of Man.

2.2. Field observations

2.2.1. By-catch data collection

Three different sources of observations of the by-catch of brown crabs in scallop dredge were used for this study. Fishery-independent data were collected between 2009 and 2012 during scallop stock assessment surveys on board the R.V. Prince Madog (using commercial scallop dredges) in the northern waters of the Isle of Man (Fig. 1, Table 1). This survey enabled us to determine the spatial distribution and catch rate of crabs outside the normal king scallop dredge open season in June and September/October each year. In order to determine seasonal differences in crab by-catch during the king scallop fishing season (between November 2012 and May 2013), temporal observations (period 1: between November 2012 and January 2013, period 2: between February 2013 and May 2013) were made on-board commercial scallop boats that fished in different areas around the Isle of Man (Fig. 1; Table 1). In addition to these direct observations during the scallop fishing season, data were also collected by volunteer scallop dredge fishermen using a crab by-catch recording form (Appendix A).

For each tow on the research vessel, the following characteristics were recorded for each brown crab: sex, reproductive state of females (berried and non-berried), carapace width (CW), and moult

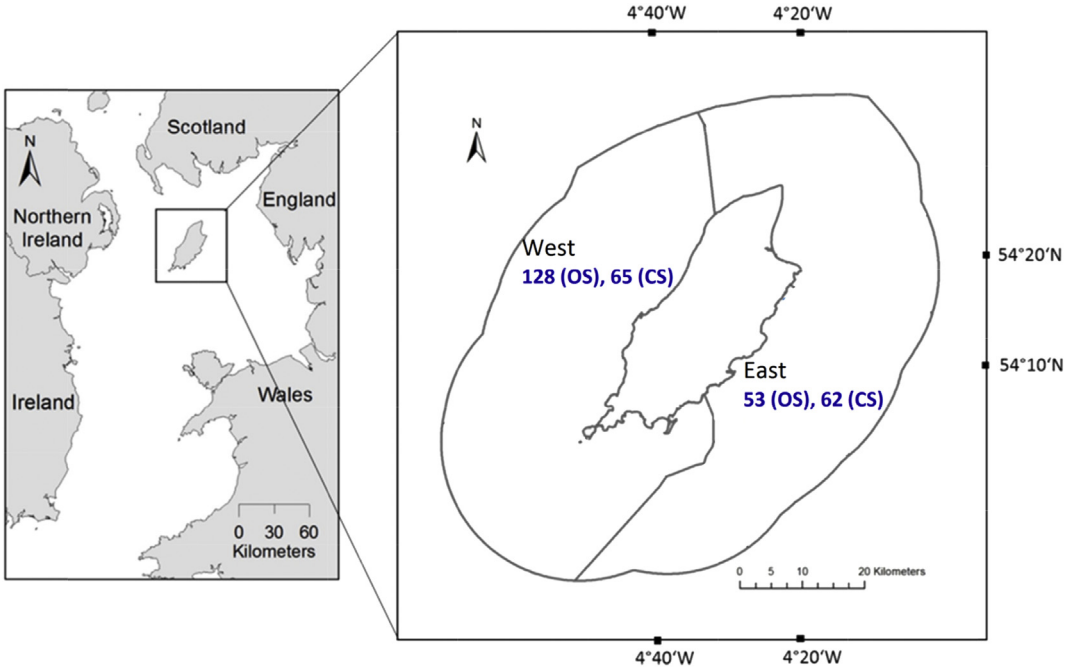

Fig. 1. Location of the dredge survey areas in Manx waters. Fishing grounds were categorized in 2 classes (West and East). Figures within fishing grounds indicate sample size (tow number) *n*. The abbreviation: OS; open (fishery) season, CS; closed season.