LANDINGS, EFFORT AND ECONOMIC PATTERNS IN THE SMALL-SCALE, DIRECTED *LOLIGO FORBESII* FISHERY IN THE MORAY FIRTH (NE SCOTLAND): A CASE STUDY USING FISHER'S KNOWLEDGE AND FISHERY STATISTICS

Jennifer M. Smith
School of Biological Sciences
University of Aberdeen, UK

Graham J. Pierce
School of Biological Sciences
University of Aberdeen, UK

Ioannis Theodossiou
Business School
University of Aberdeen, UK

Introduction

As primary resource users, fishers are most likely to recognize changes in environmental and biological conditions as they occur both intra- and inter-annually, and can often relate changes in catch to the effects of these ecological shifts. Although fishers might lack the biological knowledge required to identify the exact mechanisms involved in a changing fishery, their observations can yield valuable insights, which can be explored further by scientific investigation (e.g., see Postuma and Gasalla, 2010).

The long-finned squid *Loligo forbesii* occurs in the northeast Atlantic and is generally fished for by small, artisanal fisheries, often using handmade or bespoke fishing gear, but also taken as by-catch of trawling. In Scottish waters, *L. forbesii* is the most important cephalopod species targeted in terms of quantity of landings and value (Boyle and Pierce, 1994). In *L. forbesii's* northern UK range, wide fluctuations in abundance by both area and season have been recorded (Boyle and Pierce, 1994). Lower abundance in summer months may indicate that the animals move outside the range of the fishery and into deeper waters or simply that winter breeders die before summer (Collins et al., 1999). Pierce and Boyle (2003) found fishery abundance in coastal waters to be correlated with several annual environmental indices, including winter NAO and the average sea surface temperature (SST) and sea surface salinity (SSS) in the northern North Sea.

The commercial squid fishery in the Moray Firth (located within ICES area IVa) operates primarily in coastal waters (Pierce et al., 1994a) and is comprised mostly from landings of *L. forbesii* (Boyle and Pierce, 1994; Pierce et al., 1994a, b, 1998). The fishery typically includes catch during the months of August through November, and has historically been small-scale, with 2-3 vessels off each fishing area participating in the directed fishery each year (J. Brown, SFPA, pers. comm., 2006). During 2003, a larger fishery with over 65 boats (Young et al., 2006) was established approximately 50 m offshore from the port of Buckie, with increased landings seen throughout the Moray Firth. In 2006, there was a sharp decline in the fishery, as landings dropped substantially from those of the previous few years.

Squid fishing in Scotland operates in the absence of regulation or management, with the sole exception being an imposed minimum mesh size of 40 mm. Although recent work has focused on by-catch, discards, fishery biology and stock assessments (Hastie et al., 2009), little is known about fishing effort, fishing grounds and the financial importance of the Moray Firth directed squid fishery to the area and its resource-users, particularly during the highly varied monthly and yearly catch rates of the past five years. The present study attempts to use both fishers' knowledge and government fisheries statistics to identify the importance of the *Loligo* fishery in the Moray Firth as a resource in terms of (a) landings and (b) revenue, as well as (c) assess the changes in input pressure (effort) and output (catch) over the past decade. We also attempt to increase the knowledge of potential spawning ground locations and fishers' opinions towards regulation, both of which are vital to any future efforts to preserve the biological and socio-economic sustainability of this variable fishery.

Materials and methods

Interviews

An interview questionnaire was developed to collect vessel and trip information, gear specifics, biological and economic catch details, management suggestions, and opinions regarding the decline of landings during the 2006 fishing season as compared to the higher landings from previous years. Fishers who had participated in directed fishing during the years surrounding the fishery decline were targeted in early 2007 (total: n=13; directed squid fishers only: n=11). During July 2009, a second interview survey of fishers who had seen evidence of squid eggs active in the areas of the southern Moray Firth ports was conducted in order to determine possible spawning grounds for *L. forbesii* (n=6).

Fishery data

Time series data from 1999-2008 for all squid landed in southern Moray Firth ports were obtained from the Scottish Executive, including daily landings, number of boats responsible for the landings, and the associated market value.

Analysis

Daily landings and value data in each reported port were summed to give total monthly and total yearly landings quantities (tonnes), total market value (GBP£) and total vessels responsible for landing squid at each port and for the Moray Firth as a whole. Fishing effort (E_h) was calculated in hours and was defined by the amount of time fishing gear was in the water and was calculated from the number of boats responsible for daily landings (B_d), the average number of trips per day (per boat) (T_d), the average number of hauls per trip (H_t) and the gear 'soak time' (in hours) for each haul (ST_h), according to the following equation:

$$E_h = B_d \times T_d \times H_t \times ST_h$$

Catch per unit effort (CPUE) was defined as the sum of liveweight landings per day (tonnes), divided by daily effort, and gives an abundance index according to catch removed while gear is actively deployed.

Results and discussion

Vessel and trip information

The southern Moray Firth ports of Buckie and Fraserburgh are the principal sites for the majority of the squid landed in this region. West of Buckie, < 10 m boats engage in the directed fishery, and eastward the fishing is dominated by vessels > 10 m. Interview results suggest that the owners of < 10 m vessels perceive larger vessels as a threat to the fishery and future catch due to their increased power, hopper trawl nets (which have the potential to cause damage to the spawning grounds and increased catch capacity) and area rights infringement, including larger vessels traveling west from their home ports in search of better fishing grounds.

The strategy employed is to catch animals when they are either ascending in the water column to feed or descending after feeding, which indicates that the fishers are in tune to the diurnal movement patterns of the population. Fishers begin the directed season catching squid in shallow, near shore waters and progressively move to deeper, offshore waters, which corresponds with previous research that has suggested that the animals undergo a seasonal migration during their life cycle from inshore nursery grounds to offshore waters in this region (Collins et al., 1999; Viana et al., 2009).

Catch data and evidence of cephalopod eggs

During the last decade, the Moray Firth squid fishery experienced a peak in landings during the years 2003-2005, after which landings returned to levels similar to those previously recorded (Figure 1). The sharp decline in landings in 2006 from that of the prior few years could possibly be viewed as the fishery simply returning to the pre-established baseline level of landings, as opposed to a population "crash" or failure of the fishery to materialize.

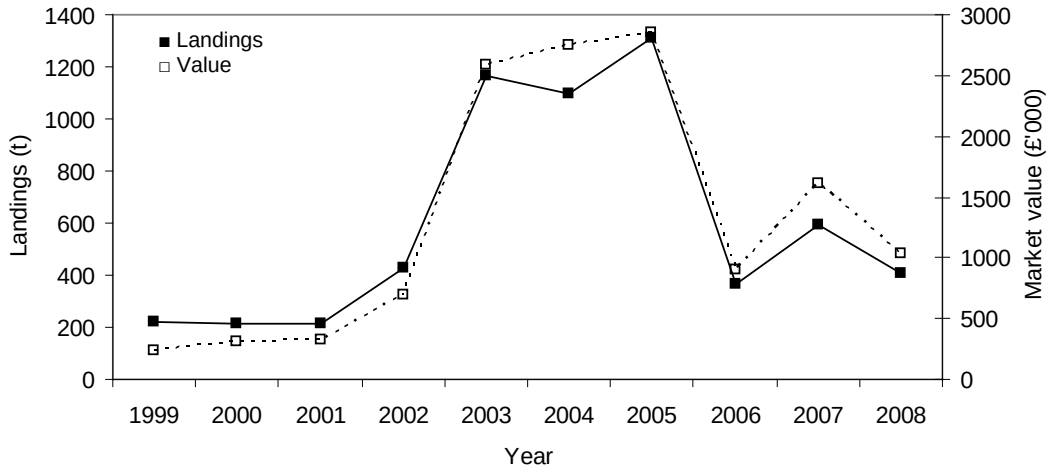

Figure 1. Total squid annual landings and market values (1999-2008) for Moray Firth ports combined, Scotland.

Landings showed a consistent seasonal pattern among both the Moray Firth ports as a whole and individually, with peaks in landings occurring during the fall months (Figure 2).

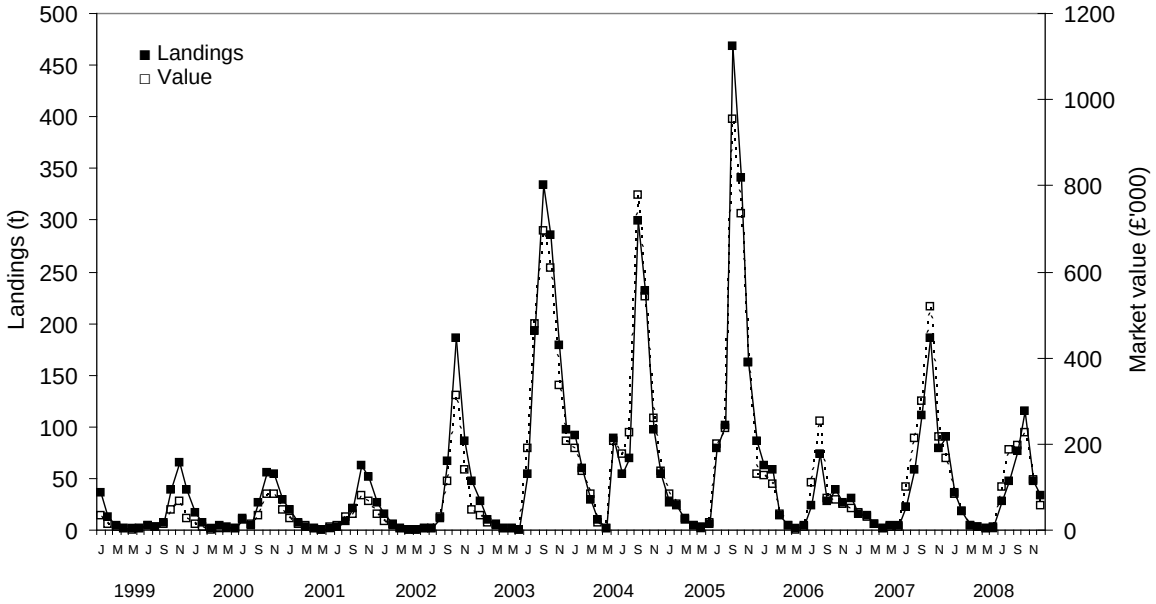

Figure 2. Total squid monthly landings and market values (1999-2008) for Moray Firth ports combined, Scotland.

The mean yearly CPUE for all Moray Firth ports combined follows a weakly increasing trend from 1999 through 2005 where it peaked, after which CPUE decreases in 2006 with the decline in the fishery, experiences a temporary increase in 2007, followed by another decrease in 2008 (Figure 3). Mean monthly CPUE calculated for all Moray Firth ports combined displays a seasonal pattern, with a peak in CPUE value in the fall during the months of either August, September or October (Figure 4).

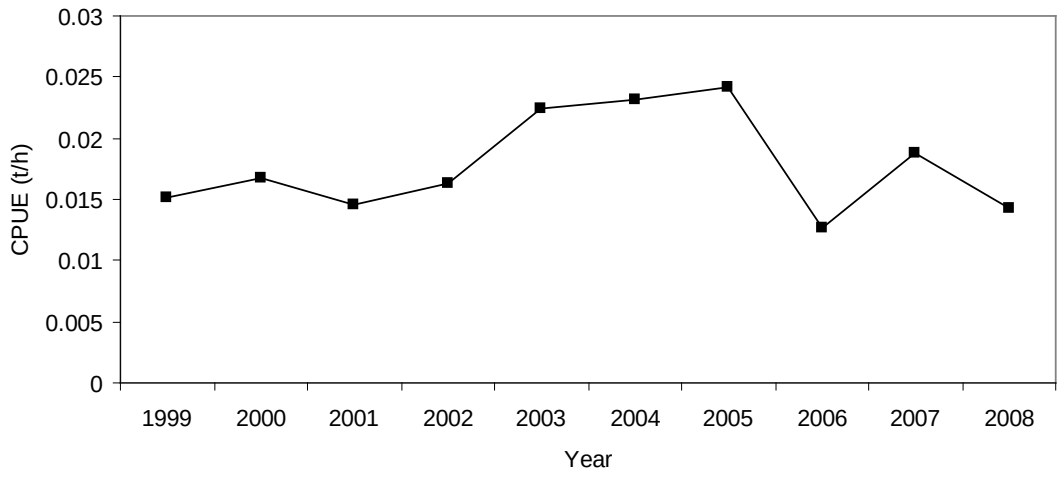

Figure 3. Mean annual squid CPUE values (1999-2008) for vessels landing in Moray Firth ports combined, Scotland.

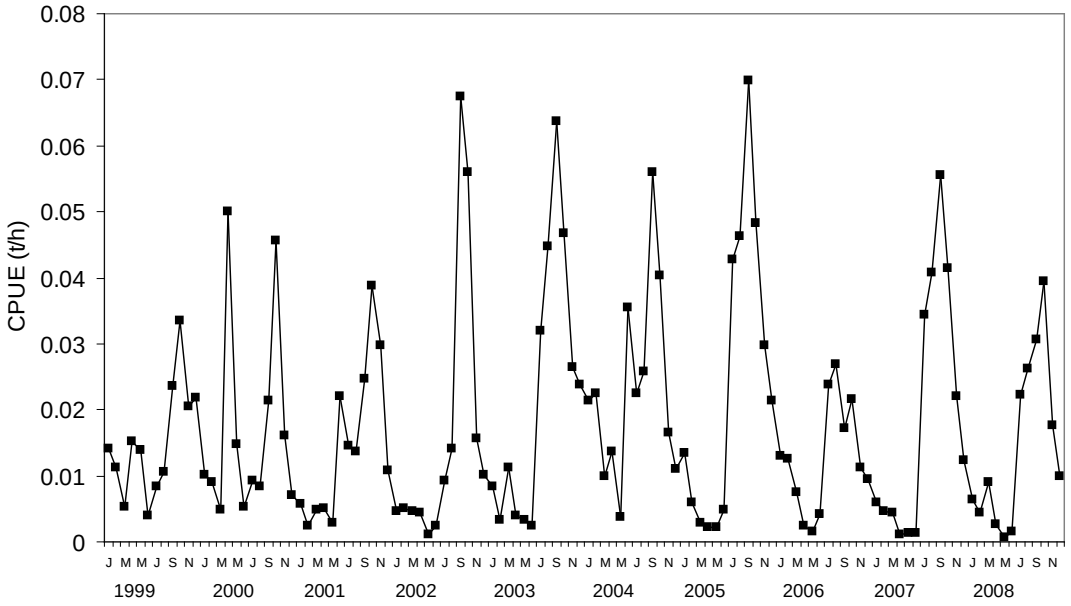

Figure 4. Mean monthly squid CPUE values (1999-2008) for vessels landing in Moray Firth ports combined, Scotland.

Fishers who commented on the presence of squid eggs during the spring and summer of 2006 expressed the opinion that there were more eggs present than had been seen in the previous years in the same area. What has been described as an overabundance of eggs seemed to have generated a larger interest in the fishery, and this phenomenon was attributed by interviewees to causing an initial increase in effort in the form of larger size and higher numbers of vessels entering the fishery at an earlier time during 2006. From the results of the current study, when looking at effort and landings as a whole across the Moray Firth, there is no evidence of increased effort in the months of June and July of 2006 when compared to that of the same months in 2003-2005. In fact, in most cases, effort during those months in 2006 is actually lower than that of 2003-2005, which seems to provide evidence against the argument of a large-scale early entry to the fishery being responsible for a reduction in catch and landings. However, as all interviewed fishers commented on the very small animals that were caught when directed fishing commenced in 2006, it is obvious that directed fishing began before the animals had reached a growth stage adequate for landing. It is possible that other biological or environmental factors influenced the number of animals that hatched and were able to grow to adult size during the peak in landings of 2003-2005 and during the decrease in landings experienced in 2006, or else something either negatively impacted the survival of juvenile animals in the population or the population simply migrated to an area outside of the geographical fishing range in this region. It was mentioned by a former creel fisher that there was an abundance of blue crabs during the spring of 2006, and it is possible that the presence of blue crabs had a direct effect on eggs. Another fisher commented on the presence of Portuguese Man O'War, *Physalia physalis*, claiming that he had never seen them in the area prior to 2006. It is unknown if the atypical presence of these animals is directly related to the lower catch in 2006 as compared to the previous three years, or if they are merely a result of some other environmental change of which the decline in squid landings was also an effect.

Economics

Economic information was difficult to obtain from interviews, resulting from both the sensitivity of the subject matter and the high level of difficulty recalling exact figures in a fishery that is known to experience very variable catch and effort. For the Moray Firth fishery as a whole, fishers gained much more in income for effort spent in 2003-2005 than for years earlier or later during the study period. This was likely an incentive for more fishers to enter the directed fishery in the consecutive seasons after 2003 and for existing participants to invest in new gear or gear repairs in anticipation of the continuation of high landings.

Future management strategies

Fishers gave the following suggested explanations for the decline in landings during the 2006 fishing season:

- Larger boats with rock-hopper trawls damaged the spawning grounds or began fishing too heavily and removed too many animals when they were of small size;
- Fishers started fishing too early (e.g., trawling in June as opposed to August as in previous years) before squid were to size;
- Changes in the water temperature;
- Combination of strong tides with easterly gales;
- Changes in the availability of the squid population's food sources;
- Velvet crabs possibly feeding on cephalopod eggs.

Fishers interviewed generally gave a positive response when asked if they would be in favor of a selection of suggested management strategies (Figure 5). As numerous fishers claimed to be willing to have observers on board, further investigation should involve the use of monitoring to collect data on gear specifics and fishing ground location. As indicated by fishers' observations of egg masses, the southern coastline of the Moray Firth is obviously a spawning ground for squid, and identification of where egg masses have been seen and brought up should be mapped more specifically using surveys on fishing boats with GIS technology or by obtaining latitude and longitude from vessel equipment. This data would enhance estimates of spawning grounds for each season, and potential temporary real-time closures of nursery grounds could be considered if damage to the area by trawling is of a high perceived or measured threat to the survival of new recruits to the annual fishery.

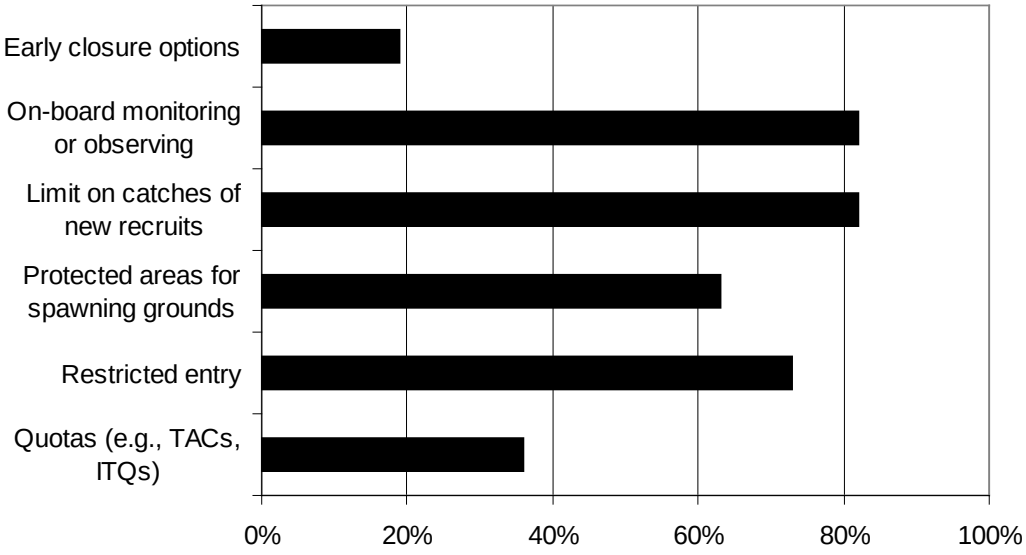

Figure 5. Percentage of squid fishers interviewed (n=11) in favour of suggested possible future management strategies.

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Corresponding author:
Jennifer M. Smith
School of Biological Sciences
University of Aberdeen
Tillydrone Avenue
Aberdeen, UK AB24 2TZ
jennifer.smith@abdn.ac.uk