Chapter 1

Introduction

Fisheries Science is the study of exploited fish stocks [3, 14]. With the advent of vessel monitoring systems, new assessment methods are needed that can make use of higher resolution catch and effort data. Some of these systems are capable of recording a time stamp and global positioning system coordinates for each unit of effort. Looking at continuously collected data has challenges, the analyst has a choice to bin the data by weeks, month, years, or even hours or minutes. Depletion estimation of abundance is an established method, [7, 19], and seasonal catch and effort data are becoming easier to obtain. Modern computing tools make fitting dynamic models much easier; it is easy to imagine the use of depletion models on daily, weekly, or monthly catch and effort series. One good example of a fishery where this idea has been applied is the Moroccan octopus fishery [22], where recruitment and harvest were estimated on a weekly time step. For instance, weekly models have seen some use in invertebrate fisheries [9, 11, 22]. Given the number of weeks in a year, significantly more data are available in systems with weekly collected data compared to systems which collect data annually. Despite this, relatively few tools have been developed that use weekly data to study the processes of recruitment, mortality, harvest, and growth. Some well studied invertebrate fisheries that do use weekly or monthly models include the Northern Prawn Fishery in Austrailia [10], and neon flying squid in the Pacific [6].

Such weekly depletion models, particularly when coupled with size composition data, are able to provide estimates of realized, as opposed to targeted, exploitation rates. With periodic size (or age composition) data, natural mortality and seasonal patterns in vulnerability can also be studied.

Most fisheries have some combination of input and output regulations imposed on them. However, there are few tools that are capable of integrating input and output regulations, market forces, physical limitations (e.g., weather), population dynamics, and the growth in size of individuals and the life cycles of harvested species into an understanding of temporal patterns in the exploitation rate. This is largely due to few within season assessment models having been developed[22]. Few management strategy evaluation models are capable of evaluating commonly-used management choices, such as seasonal closures, size restrictions, and restrictions on the number of licenses. Within season models would allow for the simulation of non-regulatory constraints and drivers of fishermen behavior. Seasonal models may be particularly important to some of the valuable effort-controlled fisheries, such as the Dungeness crab fishery and the Atlantic lobster fishery.

Management strategy evaluation has been increasing in popularity as a tool to evaluate the performance of fishery regulations [21]. However, it is rare that management strategy evaluations are used on within season management. Expanding the management strategy evaluation concept to include a more complete picture of the different limits on exploitation rates is needed to understand how management choices are likely to affect the social, economic, and ecological dimensions of fisheries. There is increasing understanding that fishery management is about ”people, not fish” [12, 25]; this can only be especially important in fisheries with complex seasonal patterns in the amount of latent (capable of being deployed, but still tied up on shore) effort [25]. Within season depletion models allow for the simulated evaluation of seasonal management regimes that are impossible under annual operating models.

This dissertation develops a within season depletion model for the Dungeness crab fisheries. It then uses the model to simulate different input controls including changes to the number of vessels in the fleet and rules regarding opening and closing the fishery to evaluate how much catch is lost due to softshell handling.

1.1 Dungeness Crab Fishery

For this analysis the Dungeness Crab Fishery in the Hecate Strait was used as a case study, however Dungeness crab fisheries are conducted from Alaska to California [8]. This section provides the relevant background information on the biology, economics, and history of the fishery.

1.2 Biology

Dungeness crab (Cancer magister [1] or Metacarcinus magister [2]) have a complicated life history including a several month period as pelagic zooplankton [23]. While this thesis is not the place for a detailed exposition of everything known about their life history, it is important to review some relevant details that are important to management. There has been some effort made mapping how zoea are currently distributed along the pacific coast [15, 16]. In the late spring or early summer, zoea moult into the megalope life stage and the currents bring them close to shore [18]. During their first two years, they moult often, but as the crabs grow in size they moult less frequently until reaching three years of age, when they only moult about once a year [24]. In subsequent chapters, crab growth is discussed in greater detail.

To reproduce, a male must be wider than a female crab, while females can only receive a sperm plug when their shell is soft and can fertilize multiple (annual) batches of eggs from a single sperm plug [20] [13]. Since the Dungeness crab fishery exclusively targets large males, concerns have been raised that recruitment may be impacted by females failing to find large males to mate with. However, Hankin et al. [13] did not find any evidence for that.

1.3 Coastwide history of the Dungeness crab fishery.

Whole books could be written about the development of the Dungeness crab fishery, detailing the different types of traps used by decade, the bottom trawl fishery, the transition from selling canned crab meat to live crab, and countless other shifts in climate, ecology, technology, and economics that shaped this fishery. This thesis does not attempt to undertake such an endeavor. In particular there are some well-studied cycles in California [4, 5, 16] and long-term time series of annual landings in British Columbia that are important context to the analyses undertaken in subsequent chapters.

1.3.1 California Cycles

Dungeness crab landings in Northern California have historically fluctuated in a nearly cyclic manner, with six or seven years of high production followed by about four years of low production. A summary of these cycles is shown in table 1.1. The California cycles were the subject of significant study because they occurred with such regularity. It is of note that there was almost an order of magnitude difference between the years of high production and the years of low production. Several hypotheses have been proposed to explain the periods of high and low productivity including oceanographic conditions, lags in fishing effort, and cannibalism [4], [5], [16]. Looking at long-term records Johnson et al. [17] shows that somewhat regular periods of high and low production occurred in Washington and Oregon as well.

Years	Average landings (lbs/year)
1955-1961	9,755,310
1961-1965	1,922,148
1965-1971	10,474,386
1971-1975	1,281,444
1975-1982	13,330,590
1982-1984	4,587,442

Table 1.1: Crab landing Cycles in California

1.3.2 Historical Catches in British Columbia

These figures come from data in the book written by Jim Boutillier at Fisheries and Oceans Canada (D.F.O); I do not know if the book was ever properly published. It is not entirely clear how to map the data to geography as maps showing what area in text corresponds to what area in reality are difficult to find. That said, Figure 1.1 corresponds to the area near the Skeena river which is near the Hecate Strait.

1.4 Management

Dungeness crab are managed in British Columbia under a collection of regulations: only male crabs larger than 165 mm with hard shells can be harvested [8] and there are restrictions on the number of vessels that can fish in a given area, the size of the vessels, and the number of traps per vessel [26]. Finally, to avoid intensive fishing during time periods when many soft shell males are present, there are area dependent rules to close the fishery during a moult.

There are a few things to consider about the management regime: the size restriction is effectively a sex restriction, and few female crabs are larger than $165mm$. Also the major markets for B.C. crab are China and the United States of America, so any discussion about bringing soft shell crabs to market would have to consider the logistics of live shipment of soft shell crab.

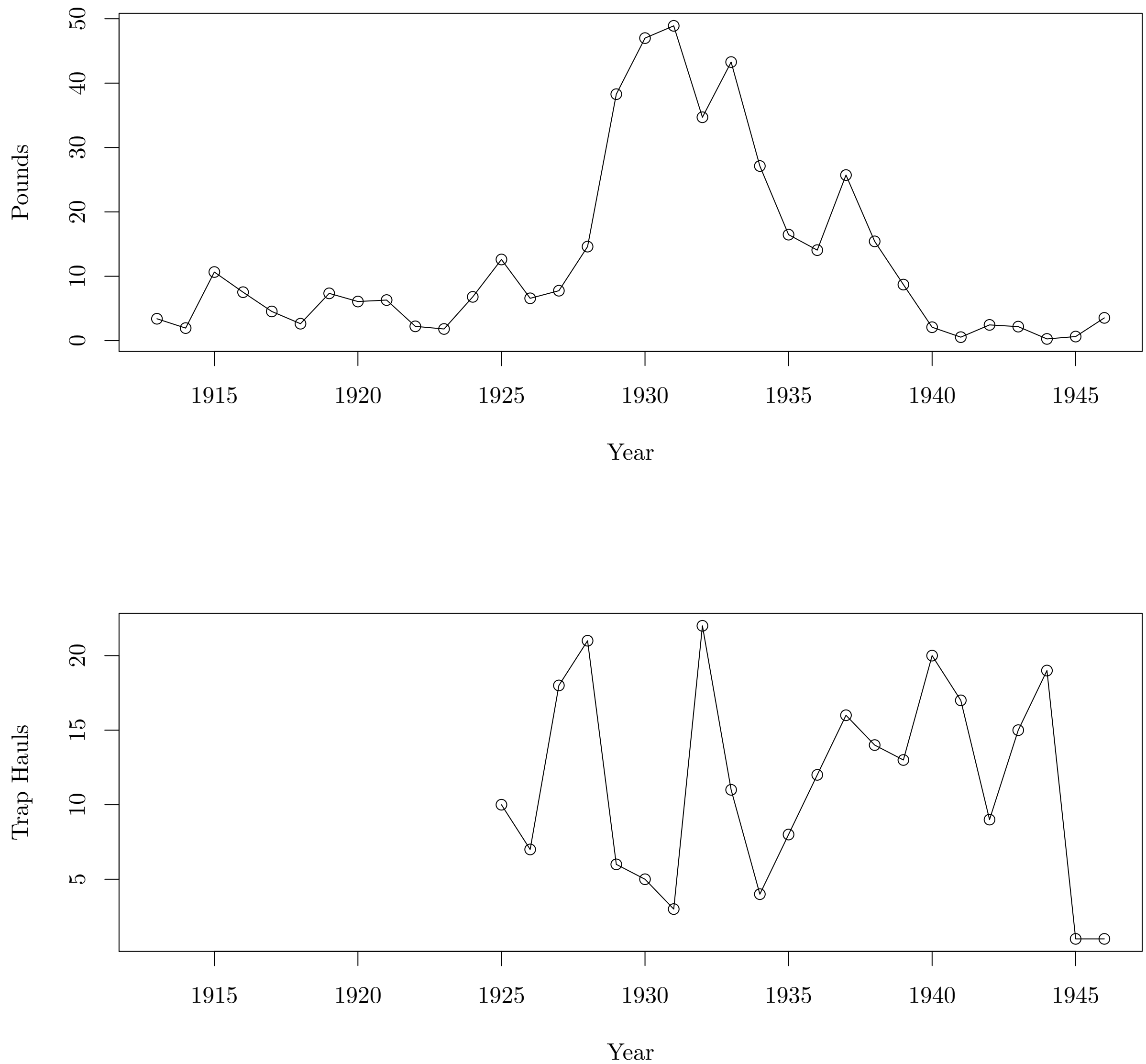

Figure 1.1: Effort as predicted by catch per trap haul.

1.5 Economics

Yonis [26] points out that there were 9 vessels larger than 52 meters that could deploy up to 1200 traps in the Hecate Strait (known offically as Area A). There were also 10 vessels between 42.5 meters and 52 meters that could deploy between 800 and 1000 traps. The remaining vessels were less than 42.5 meters and could deploy up to 600 traps.

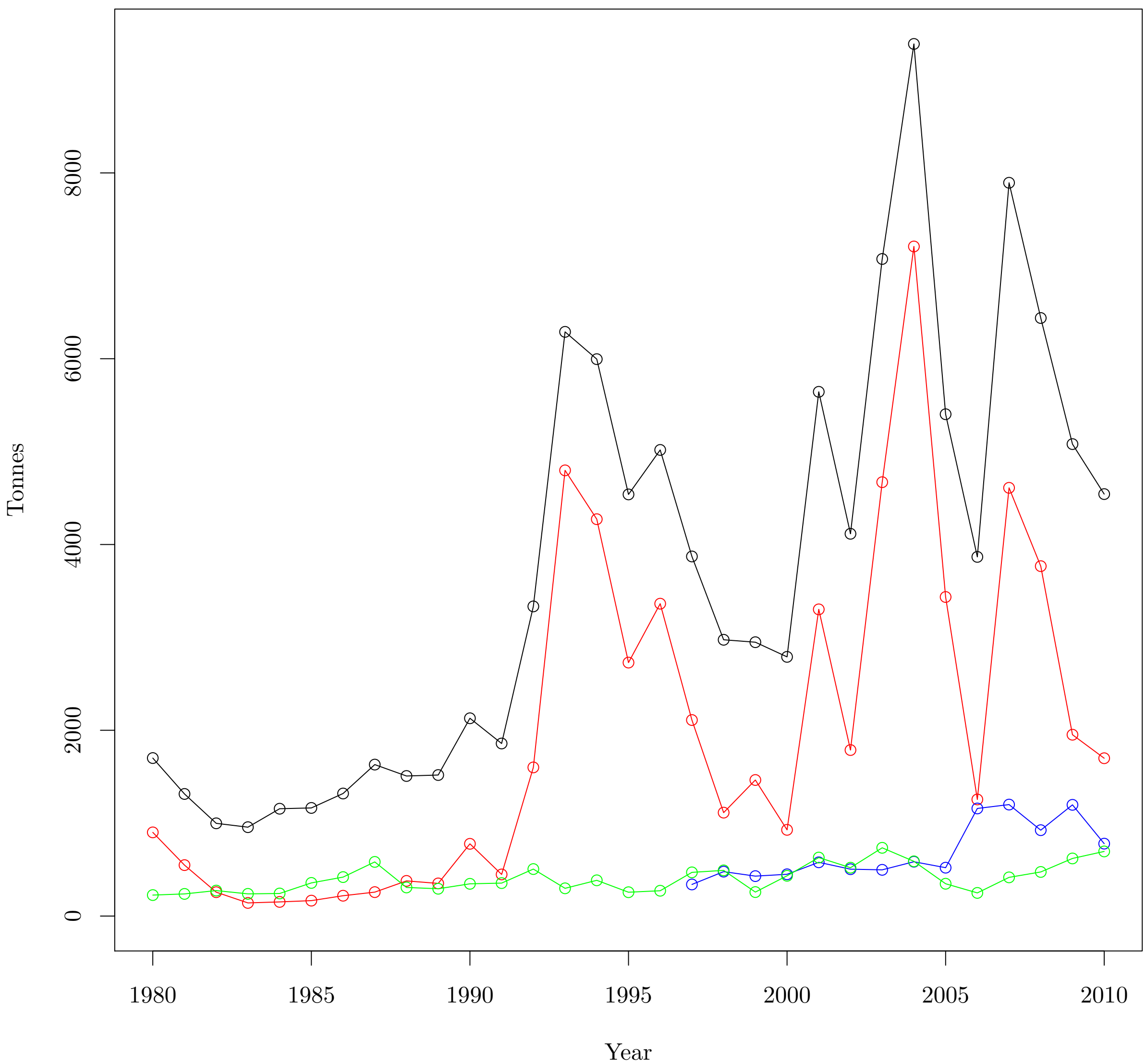

Figure 1.2: Landings in B.C.

Yonis [26] estimated that the fleet average crew share was $\$97,835$ with the "bottom tier" earning $\$29,097$ and the "top tier" earning $\$198,072$. This is much higher than the crew shares in the other areas, which had a mean of $\$24,063$.

The crab fleet is one of the least diversified fleets in British Columbia, 80% of the fleet has only a single license and 96% of the fleet has less than two different fishing licenses [26]. This is primarily due to the fact that crab boats are specifically built for crabbing.

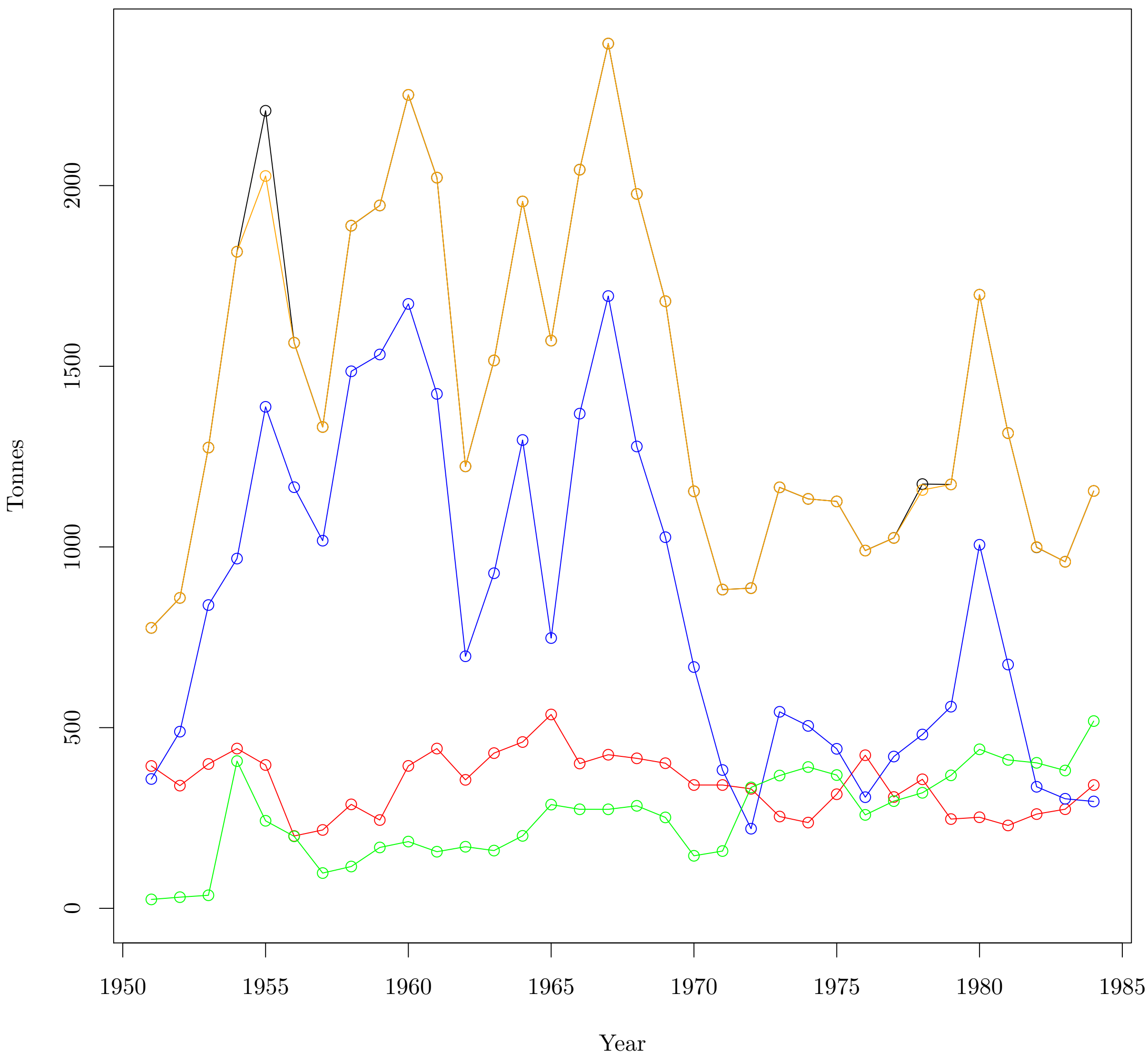

Figure 1.3: Landings in B.C.

The top third of the fleet in Area A accounted for almost 60% of the catch in 2007[26]. The bottom third of the fleet accounted for only 13% of the catch.

Yonis [26] points out that price fluctuates over the course of a year. In spring of 2008 (March, April, and May) the price per kilogram was about $10 but in July it droped down to about $8. From personal communication I have discovered that there are two hypothesis to explain why prices seem to drop when Area A opens. The first hypothesis is that Area A lands so many crab that the spike in supply drops the price of crab. The second hypothesis is that shipping live crab from the Hecate Strait results in an inferior product commanding a lower price.

The United States of America, China, and Hong Kong are the leading markets for crab Yonis [26]. There may be tacit agreements to time the Washington and Oregon crab fisheries out of sync with the B.C. crab fishery to maintain market prices, although it is unclear how important this is compared to weather and the seasonal dynamics of hard shell crab.

The following chapters examine the Dungeness crab fishery in the Hecate Strait in British Columbia as a case study. There are four chapters in this thesis: a chapter that completes an empirical analysis of effort patterns over the course of the fishing season, a chapter that develops and fits a weekly depletion model to the weekly catch and effort data, a chapter that extends the depletion model to incorporate size composition data, and a chapter that simulates three different rules involving the opening and closing dates of the fishery. Incorporating size composition data allows for the investigation of natural mortality and time changing patterns in vulnerability. Vessel Monitoring System data opens up the potential to study fine scale temporal, and in some cases spatial, relationships between fishing effort, resource abundance, and catch; new tools are needed to make the most of this relatively modern source of data. This thesis seeks to develop some of these tools.

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