# POLICY AND MARKET ANALYSIS OF WORLD DOGFISH FISHERIES AND AN EVALUATION OF THE FEASABILITY OF A DOGFISH FISHERY IN WATERS OF ALASKA, USA

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## Abstract

Spiny dogfish is a valuable commodity on the world market and has a global capture distribution. There are three chapters evaluating dogfish markets and fisheries in this dissertation; Chapter 2 evaluates the spatial distribution of dogfish in the Gulf of Alaska; Chapter 3 provides an overview of world markets and evaluates conditions that have led to a decline in dogfish product demand in Europe; and Chapter 4 uses the information from the previous 2 chapters to provide and policy and market overview of dogfish fisheries in Alaska. Results from this study provide a comprehensive world overview of the modern dogfish fisheries and market segmentation using an evaluation of trade and price statistics. These results indicate that the dogfish market is adulterated, supplied by both sustainable and non-sustainable dogfish sources. Media attention resulting from overfishing has reduced demand for dogfish products in Europe due to the adulterated market. Overcoming the loss of market share will require eco-labeling to inform consumers about sustainable dogfish stocks. The impact of eco-labeling in Asian countries is less clear due to unknown inter-Asian market channels for fins and meat and little information on consumer attitudes towards labels. Alaska products could leverage either Asian or European consumers, but a profitable fishery will likely require regulatory changes and improved stock assessment to allow a directed fishery. In addition, pending regulatory changes, establishing robust market channels between Alaska and Europe will likely require some form of eco-labeling; especially given current eco-labeling efforts in Canada and the Atlantic US.

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# Chapter 1 Introduction

Spiny dogfish is a common market name referring to elasmobranch species in the *Squalus* genus. Sharks in this genus are found in temperate coastal areas of the Pacific Ocean, Atlantic Ocean, Mediterranean Sea, and Black Sea (Compagno 1984). The common market trade name applies to several species: *S. acanthias* and *S. mitsukurii* that are widely distributed in the Pacific and Atlantic Oceans; *S. suckleii* is found in northern Pacific Ocean; *S. megalops* in the western Pacific Ocean, including waters off New Zealand and Australia; *S. montalbani* and *S. edmundsi* that ranges from the eastern Indian Ocean to the Pacific Ocean; *S. cubensis* and *S. mitsukurii* in the southern Atlantic Ocean and Pacific Ocean; *S. japonicas* and *S. brevirostris* in Pacific Ocean waters off Asia and the China Sea, *S. cubensis* found in the Atlantic Ocean off the coasts of South and Central America, the Gulf of Mexico, and off the coast of the southeastern United States (US); and *S. blainville* found in the eastern Atlantic Ocean, Mediterranean Sea, and Black Sea.

Historically dogfish fisheries have experienced boom and bust cycles caused by biological or market forces (Gasper, Kruse, and Greenberg In prep; Ketchen 1986). Market share for spiny dogfish generally increases as product gains popularity or harvest provides fishing opportunities, creating a boom. A bust occurs when the market disappears or mismanagement results in stock collapse. During the 2000s, market share for dogfish products declined sharply during a period when North Atlantic dogfish stocks declined from higher levels observed during the 1990s (ICES 2006). Dogfish stocks are data poor with inadequate information about harvest and stock status in many areas of the world. These data concerns, coupled to known stock depletion issues in the North

Atlantic Ocean, prompted the EU and environmental groups to petition CITES to regulate dogfish trade (CITES 2003; CITES 2007; CITES 2010).

There were two primary motivations for this study. First, this study characterizes the world trade of dogfish and how market structure could be leveraged to encourage sustainable use through product differentiation and eco-labeling. Second, this study investigated issues associated with developing a dogfish fishery in waters off the State of Alaska, including marketing and regulatory issues; biological constraints associated with harvest; and supply chain logistics and quality control. When considered a whole, this dissertation provides direction towards establishing dogfish as part of the seafood portfolio for Alaska.

This study was partially funded under the United States Department of Agriculture New Crops Opportunities for Alaska (grant number 0207561). The dissertation is divided into three chapters, each providing information about a different element of dogfish fisheries and associated markets. The first chapter is focused on characterizing the distribution of dogfish in the Gulf of Alaska using quantitative modeling techniques. The second chapter uses international and US trade statistics, statistical techniques, and informal interviews with industry constituents to evaluate market structure and segmentation, trade flow, and sustainability issues. The last chapter uses information from the previous two chapters to evaluate marketing and regulatory barriers for establishing a dogfish fishery in Alaska. A simulation of potential catch under the 2011 regulatory environment is used to evaluate economic effects and inform managers about regulatory adjustments that may improve economic viable for the fishery.

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# Chapter 2 Spatial modeling of the distribution of spiny dogfish (*Squalus acanthias*) in the Gulf of Alaska using generalized additive and generalized linear modeling techniques[1]

## 2.1 Abstract

The spiny dogfish (*Squalus suckleyi*) is a common bycatch species in commercial longline fisheries in the Gulf of Alaska. This small shark is widely considered a nuisance and most dogfish catch is discarded. Their spatial distribution in the Gulf of Alaska is poorly understood. A better understanding of areas of high bycatch would provide critical information to fishery managers, whether they seek to convert discards into valuable fishery landings or to manage fishing mortality on this long-lived species. We analyzed the spatial distribution of the spiny dogfish from fishery dependent and fishery independent data collected between 1996 and 2008 using generalized additive and generalized linear modeling techniques. Poisson, negative binomial, and quasi-Poisson error structures were investigated using goodness of fit statistics. The quasi-Poisson generalized additive model provided the best fit. Modeling results showed that longline catches of spiny dogfish were concentrated east of Kodiak Island, Alaska, with increased spatial homogeneity of dogfish between the eastern and western GOA. The number of dogfish caught

[1] Gasper, J.R.,G.H. Kruse, and J. Greenberg. (In prep). Spatial modeling of the distribution of spiny dogfish (*Squalus acanthias*) in the Gulf of Alaska using generalized additive and generalized linear modeling techniques. Prepared for submission to Canadian Journal of Fisheries and Aquatic Sciences.

generally showed a decreasing trend with increasing depth and decreasing number of hooks. However, depths between 1 and 100 meters had the greatest positive influence on dogfish catch. Areas of high dogfish bycatch indicate core areas that may be important to future considerations of stock assessments, at-sea discard estimation, and fishery management.

## 2.2 Introduction

Fishery scientists have long recognized the need to understand spatial patterns of fish stocks and fisheries. For instance, the spatial distribution of spawning grounds is one of the oldest methods to define stocks as management units (Gulland 1983). In the U.S., essential fish habitat for each stock is taken to mean "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity" (NMFS 2007). Recently, it has become widely appreciated that a frequent cause of overfishing is the failure to fully account for total fishing mortality over the full range of a stock. Considerations of spatial distribution have become particularly important as fish stocks become scarce in some regions of the world, resulting in fishery regulations specific to small geographical areas and, in some situations, small catch quotas (Weber 2002). In response to these concerns, management agencies throughout the world have promulgated area-specific regulations to protect prey availability for charismatic species, such as marine mammals, or to reduce bycatch mortality of economically important species.

As examples, in Federal waters off Alaska, annual catch limits (ACLs) for groundfish species are spatially apportioned among federal reporting areas and among fishing seasons (Figure 2.1). In overview, science-based overfishing levels (OFLs) and acceptable biological catches (ABCs) are implemented for each stock or stock assemblage, whereby a buffer is specified between OFL and ABC to avoid overfishing (DiCosimo et al. 2010). Total allowable catches (TACs) are then set by the North Pacific Fishery Management Council (NPFMC), such that the TAC for any species or assemblage is less than or equal to the corresponding ABC. Each fishery is closed when the total catch for a species or assemblage is estimated to attain the TAC. A revision to the Magnuson-Stevens Fishery Conservation and Management Act in 2006 (MSA) required the establishment of ACLs, as well as accountability measures, to prevent overfishing. Because of the conservation procedures already in place for the North Pacific, the Council defined ACL=ABC. The decision rules to apportion an ACL must balance important biological characteristics of a fish population with economic fishery considerations. Also, in the Aleutian Islands area, groundfish harvests are banned within 10- or 20-nm radii of Steller sea lion *(Eumetopias jubatus)* rookeries and major haulouts. Fishing is also allocated among multiple fishing seasons in attempts to avoid localized depletion of sea lion prey. Spatial modeling is useful to inform such fishery management decisions about fishing impacts on biological sustainability by addressing both conservation and economic concerns.

Spatial models are particularly useful to determine catch patterns as proxies for habitat use for species that have low biological productivity and are incidentally caught in gear used to harvest more valuable target species. A good candidate for such modeling is the spiny dogfish (*Squalus suckleyi*), a small demersal shark species commonly caught as bycatch in commercial longline and other fisheries off Alaska. Small amounts of spiny dogfish are landed by a longline fishery that occurs in the exclusive economic zone (EEZ) in the Gulf of Alaska (GOA; Figure 2.1); annual retained catches averaged <3 metric tons between 2004 and 2008. Although the directed fishery is small, spiny dogfish are incidentally caught and discarded in many fisheries for other more economically desirable species such as sablefish (*Anoplopoma fimbria*), Pacific cod (*Gadus macrocephalus*), and Pacific halibut *(Hipploglossus stenolepis)*.

Spiny dogfish are particularly vulnerable to over-exploitation due to a life history that is characterized by late age at maturity (35 years for females; Saunders and McFarlane 1993), longevity (>100 years; Vega et al. 2009), low fecundity (6-10 pups; Tribuzio et al. 2010b), and a complex stock structure. Tagging studies conducted in British Columbia and Washington State show segregation of spiny dogfish into local resident and migratory populations (King and McFarlane 2003; Taylor 2008). The population structure of spiny dogfish in Alaska is unknown and the species is currently managed as a single population in the GOA. The NMFS assesses the status of spiny dogfish based on trends in survey and biological data in its annual stock assessment and fishery evaluation reports (Tribuzio et al. 2010 a). However, there is not currently an established population assessment model for spiny dogfish; future modeling attempts need to consider the spatial distribution of spiny dogfish in the GOA.

Catch per unit effort (CPUE) indices have implicit assumptions about catchability that require careful consideration of fishery and species interactions such as changes in fishing power, vulnerability of a species to gear, changes in stock abundance, temporal and spatial changes in species distribution (Winters and Wheeler 1985; Pereira and Leandro 2009). Indices of abundance are also related to the scale at which they are calculated. Indices based on fishery-dependent data can mask changes in biomass and population structure due to hyperaggregation, which creates an illusion of high biomass and may result in highly variable estimates due to non-optimized data stratification (Rose and Kulka 1999). This is especially true for a species such as spiny dogfish because they exhibit strong schooling behavior by sex and life stage that cause patchy distributions that influence catch estimates used in stock assessments. Despite these concerns, lacking an assessment of dogfish biomass, historical catch is used to set ACLs for spiny dogfish in the GOA under the questionable implicit assumption that it is an appropriate index for future sustainable fishing mortality.

Presently, the ACL for the "other species" complex in the GOA includes all sharks, octopus, sculpins, skates -other than big skates *(Raja binoculata,)* and longnose skates (*Raja rhina*)-that are caught in the Federal groundfish fishery. A single TAC is set for the other species complex, but trends in fishery catch and stock abundance are monitored for each species within the complex. Average spiny dogfish catch in the groundfish fishery between 1997 and 2007 is used to estimate an overfishing level (OFL), which, if exceeded, would trigger inseason fishery closures to limit mortality when reached (Tribuzio et al. 2010 a). The OFL implicitly assumes that large catch events during short periods do not result in unsustainable fishing mortality in the long run. In 2011, the “other species” group will be split apart as part of the MSA’s National Guidelines for implementing ACLs (DiCosimo et al. 2010). The intention is to create a shark group with its own ACL (DiCosimo et al. 2010). Bycatch would accrue towards the ACL and if levels were of sufficient magnitude, some target fisheries could be closed. Thus, spatially understanding where bycatch problems and data gaps in bycatch estimates may arise will be an essential part of establishing shark species-specific ACLs.

Estimates of dogfish catch in the groundfish fishery are made using a combination of information from onboard observers, landings, and or processors using formal catch estimation methodology (Cahalen et al. 2010). In brief, onboard sampling by observers is a critical component for estimating dogfish fishery mortality because most dogfish are discarded at sea. For vessels making shoreside landings, a ratio estimator consisting of at-sea discard information collected by observers is used to estimate discards associated with these landings. The ratio is created by spatially aggregating observer information to the level of the fishery management plan area or smaller Federal reporting area (Figure 2.1), depending on the spatial resolution of observer information. If observer information at the reporting area level is not available, then information from outside of the reporting area where fishing occurred is used. This commonly happens in infrequently sampled areas and at the start of the year when observers may not have yet sampled a Federal reporting area, requiring a ratio estimator consisting of GOA-wide observer information.

Ratio estimators assume the linear relationship between the covariates is consistent with the catch characteristics of the area fished. Species with patchy distributions (such as dogfish) have spatial heterogeneity that results in large variation between areas and potential bias in the ratio estimator if non-representative discard data are used in the estimate. Further, other data attributes such as gear fished, marine mammal interactions (e.g., gear depredation), baiting method, and vessel type may also influence the accuracy of a ratio estimate. This is of particular concern for spiny dogfish because they are discarded at sea by the longline fleet, which generally has low observer coverage in the GOA. Further, longline vessels targeting halibut are not required to carry onboard observers, so estimates of dogfish bycatch are not available for this fishery. Some vessels mix sablefish and halibut trips and thus some observers cover halibut longline fishing, but the vast majority of halibut fishing effort is unobserved owing to small vessel sizes. Longline vessels fish gear on the bottom using a ground line, anchored at each end, to which hooks are attached. Lengths of ground line are stringed together in segments called skates. The length of each skate, number of hooks per skate, and number of skates depend on the size of the vessel and the species being targeted.

Onboard observers collect information from two categories of groundfish longline vessels: catcher vessels (CVs) and catcher-processor vessels (CPs). Catcher vessels catch fish that are delivered to shoreside or floating processors. In rare situations, longline-caught cod are brought to a mothership. Catcher processors catch and process fish at sea; these vessels are typically larger than CVs and may operate 7 days a week, 24 hours a day. Observers are deployed such that vessels <18.3 m are not required to carry observers, whereas those of length 18.3-35.6 m carry observers 30% of the time and those >35.6 m have 100% observer coverage. Between 2003 and 2008, CVs accounted for 96% of all vessels operating in the GOA, with CPs and a few motherships accounting for the remaining 4%. Owing to their larger size, CVs account for a disproportionate amount of the harvest and receive a larger percentage of observer coverage. In 2004 and 2007 CPs accounted for 24% of the total longline groundfish catch and 65% of the observed catch; approximately 90% of the CPs and 5% of the CVs have observer coverage (Table 2.1).

Previously, CPUE data have been used to describe trends in spiny dogfish abundance in the GOA. Conrath and Foy (2009) found CPUE to be highly variable, but without trend over time, with a higher abundance of spiny dogfish in the eastern GOA. Rice (2007) standardized spiny dogfish CPUE and found, similar to Conrath and Foy (2009), that CPUE was generally higher in the eastern GOA. His estimates suggest that Federal reporting areas in the eastern GOA tend to have a greater abundance of dogfish, but trends were difficult to distinguish due to large uncertainty and the large spatial units used in the analysis. All of these studies made use of longline survey information collected by the International Pacific Halibut Commission (IPHC) for halibut and National Marine Fisheries Service (NMFS) for sablefish, and commercial fishery information collected by the onboard observers in the North Pacific Observer Program aboard longline vessels targeting sablefish and Pacific cod. The IPHC and NMFS have conducted systematic longline surveys for halibut and sablefish in the GOA and eastern Bering Sea since 1977 (Clark and Hare 2006) and 1984 (Hanselman et al. 2009), respectively.

Our goal was to determine whether localized distributions of spiny dogfish in the GOA could be modeled using generalized additive and generalized linear modeling techniques with indices of fishing effort, spatial coordinates, and bottom depth as independent variables during the post-IFQ fishery. Further, we wanted to provide a higher spatial resolution of dogfish abundance in the GOA than previously investigated to inform managers about areas with potentially high bycatch and areas with data gaps in at-sea discard estimation. Generalized linear models (GLMs: Nelder and Wederburn 1972) and generalized additive models (GAMs: Hastie and Tibshirani 1986) are commonly used to describe and standardize fisheries catch and effort data. The two techniques are closely related; a GAM is an extension of the GLM approach by allowing non-parametric smoothing of explanatory variables (Wood 2003). Most catch-effort modeling has been conducted using GLMs (Maunder and Punt 2004), many of which incorporated spatial information both with and without data transformations. The flexibility of GAMs allows the non-parametric nature of spatial data to be explicitly modeled. For example, Bigelow et al. (1999) used nonlinear relationships between spatial covariates to model swordfish (*Xiphias gladius*) and blue shark *(Prionace glauca)* in the Pacific Ocean. Minimi *et. al.* (2007) used a smoother in a zero-inflated model to describe the catch of sharks in the Pacific tuna fishery, and Wood (2003) modeled egg counts of mackerel (*Scomberomorus spp.*) off the

Newfoundland coast. We use both the GLM and GAM models as a comparison between results.

## 2.3 Methods

### 2.3.1 Data Description

We assembled survey and fishery datasets to cover areas commonly fished in the GOA (Figure 2.1). For instance, much observer data were collected from longline CPs targeting sablefish along the GOA shelf break. The western GOA generally had more nearshore observer coverage owing to the distribution of CPs fishing in the Pacific cod fishery, whereas observer data are not available for the CV fleet targeting halibut in the inside waters of southeastern Alaska nor the nearshore areas of the eastern GOA. Therefore, survey data were used in these nearshore areas to supplement observer data, which were the primary focus of our analysis.

Both fishery-dependent and -independent data were analyzed. Fishery-dependent data were collected by observers onboard commercial longline vessels during 1996-2008. Observers use randomized sampling procedures to estimate catch for each segment of longline gear (see Cahalen *et. al.* 2010 for detailed description of the catch estimation methods used by observers). In brief, the total number of spiny dogfish estimated for a set of longline gear is based on the mean-number-per-hook expanded by the number of hooks retrieved in a given set. The total number of hooks retrieved is the total number of sets expanded by the mean number of hooks per set.

The estimated number of spiny dogfish per set was used in this analysis as well as the number of hooks set, latitude, longitude, and average bottom depth of each set.

Fishery-independent data were collected in standardized longline assessment surveys for halibut conducted by the IPHC in the GOA during 1998-2008 (Clark and Hare 2006) and for sablefish by the Alaska Department of Fish of Game (ADFG) in Chatham Strait (Southeast Alaska) during 1996-2008 (Richardson 2003). Data consisted of the total number of hooks sampled, number of spiny dogfish caught, latitude, longitude, and average bottom depth. For both the ADFG and IPHC longline surveys, the type of hooks, size of the skate fished, and station locations are standardized. These surveys both use gear configurations and methods designed to mimic those used in the commercial longline fishery. For the IPHC survey, sampled hook data only, rather than expanded estimates, were used. Expansion of spiny dogfish to the entire hook count was not straightforward in the IPHC survey, because only the first 20 hooks on each skate were sampled for bycatch, including spiny dogfish.

### 2.3.2 Data preparation

Longline retrieval locations collected by the onboard observers and surveys were summarized into 20-km$^2$ spatial blocks in the GOA using ESRI ArcMap 9.3 software and the R Maptools package (Lewin-Koh and Bivand 2010). Spatial polygons of 20-km$^2$ areas were the highest resolution that data could be displayed while meeting NMFS confidentiality requirements for fishery-dependent data (Figure 2.2). Data summarized for each polygon were either survey- or observer-based and did not overlap. For each polygon, all observed sets having latitude and longitude coordinates within the polygon were summarized, creating a shapefile containing the total number of spiny dogfish, the total log transformed number of hooks fished, and the mode depth of fishing as reported by the observer. The mode depth reflects the depth at which the highest frequencies of the average depths within each polygon were recorded by observers. We also investigated use of median depths, but it had no effect on the results.

To investigate spatial changes in distribution of spiny dogfish catch over time, the polygon shape files were grouped into four time periods: 1996-1999 (period 1); 2000-2003 (period 2); 2004-2008 (period 3); and all years combined (period 4). The duration of each period was selected to provide adequate sample sizes of observer and survey data within each polygon. In period one, survey data are available only during the period between April and September, which precluded seasonal analysis given the modeling framework. Survey data were not available for areas outside of Chatham Strait for 1996 and 1997.

### 2.3.3 Model Formulation

Generalized linear models provide a flexible framework to describe a wide variety of data with different response distributions. Such models are defined by the response distribution, a member of the exponential family, and the link function that relates explanatory variables to the mean of the response distribution. The response distribution may be continuous (e.g., Gaussian) or discrete (e.g., Poisson), but the key assumption is that the mean of the response distribution, $E(Y) = \mu = g(\eta)$, is related to the explanatory variables ($X\beta$) as:

$$g(\eta) = X\beta$$

Maximum likelihood estimates for GLMs are found using an iteratively reweighted least squares (IRLS) algorithm. Nonlinearities in the error structure between the explanatory variables and dependent variables may be incorporated into the function g($\eta$) using data transformations and interaction terms. These transformations are generally used to normalize the data to improve the relationship between the mean and variance across all data values.

General Additive Models are an extension of GLMs that allow for non-parametric relationships between the response and explanatory variables by replacing the linear component (X$\beta$) with additive non-parametric smoothing function(s), $f_p(x_i)$, such that

$$\eta_i = X\beta + f_1(x_{1i}) + f_2(x_{2i}),..., f_p(x_{zi})$$

$$g(\eta_i) \equiv E(Y_i) \; and \; Y_i \sim \text{ error distribution}$$

As with the GLM, a link function ($g(\eta_i)$) relates the explanatory variables to the response distribution, which is of the exponential family. The GAM likelihood is maximized using penalized reweighted least squares. Our study used two types of smoothing functions: a thin plate regression spine (Wood 2003) and tensor product spline (de Boor 1978). These smoothing functions optimize model fit by selecting a smoothing parameter by minimizing generalized cross validation (GCV) or an unbiased risk estimate (scaled Akaike Information Criterion) score. To avoid overfitting the model, a penalty on the smoothing parameter was imposed as the amount of model 'wiggliness' increases (Wood 2004). To further avoid overfitting, the effective degrees of freedom (EDF) used to calculate a GCV score was penalized by increasing the estimated degrees of freedom used in the GCV score by 1.4, creating a smoother fit than would otherwise occur (Wood 2003).

The GLM and GAM model formulations require careful consideration of the error distribution, the function linking the error distribution with the explanatory variables, and the explanatory variables included in the model. The dependent variable was composed of counts of spiny dogfish, which is a discrete variable that can be modeled using the Poisson or negative binomial distributions. Both these distributions allow for observations with zero values and are appropriate for discrete count data. Based on graphical analysis, the spiny dogfish counts had a large mass near zero counts with a long tail associated with higher counts (Figure 2.3). This pattern could result in overdispersion relative to the Poisson distribution. To investigate the potential overdispersion, three error distributions were investigated: Poisson, negative binomial, and quasi-Poisson. The negative binomial and quasi-Poisson both allow for overdispersion relative to the Poisson, but the relationship between the mean and variance used to calculate weights for penalized-IRLS (P-IRLS) is different for the two error distributions. The weights for the negative binomial distribution are concave to the mean whereas weights for the quasi-Poisson are directly proportional to the mean (Ver Hoef and Boveng 2007). Thus, during the P-IRLS fitting process, the negative binomial distribution tends towards weighting smaller spiny dogfish counts more heavily than does the quasi-Poisson distribution.

For the GLM models, covariates were grouped into three separate models to investigate model fit as covariates:

$$glm(\eta_{\text{model 1}}) = Hooks + \varepsilon$$
$$glm(\eta_{\text{model 2}}) = Hooks + bottom\,depth + \text{interaction} + \varepsilon$$
$$glm(\eta_{\text{model 3}}) = Hooks + bottom\,depth + latitude + longitude + \text{interaction} + \varepsilon$$

Three models were constructed for the GAM using tensor product (*te*) and thin plate regression spline (TPRS,*s*) smoothing that allow interaction between covariates:

$$gam(\eta_{\text{model 1}}) = s(Hooks) + \varepsilon$$
$$gam(\eta_{\text{model 2}}) = te(Hooks, bottom\,depth) + \varepsilon$$
$$gam(\eta_{\text{model 3}}) = te(Hooks, bottom\,depth) + s(Latitude, Longitude) + te(Longitude, Hooks) + te(Longitude, Bottom\,Depth) + \varepsilon$$

The TPRS was preferred over the tensor product smooth for model 1 and spatial smoothing parameters, because it has generally better estimation properties. In particular, the TPRS function does not require selection of knot locations, which are points in the smoothing space where corresponding basis functions are continuous up to the second derivative (inflection point) or are the end points of the spline. In addition, a basis function does not need to be chosen, as this arises naturally from the mathematics describing TPRS (Wood 2003). However, the wiggliness penalty used to fit TPRS is sensitive to non-isotropic data and is thus not appropriate for multiple covariates of differing scales. Tensor product smooths are robust against non-isotropic data and are appropriate for situations where covariates were of a different scale. A cubic spline basis function was selected for the tensor product smooth. Knot locations are evenly spaced throughout the covariate space.

In addition to modeling the counts of spiny dogfish, a GAM with a binomial distribution and logit link function was constructed using the covariates described in model 3. The purpose of this model was to look at the distribution of predicted probabilities of counts occurring in the GOA. The same spatial data previously described were used, except the presence or absence of spiny dogfish within each polygon was binomially coded as the dependent variable.

The models were fit using the MGCV package in R for each time period. Model fits for each error structure were evaluated using deviance statistics and residual analysis. The deviance statistics were the model deviance as it compares with the null model deviance, the Schwarz's Bayesian Information Criterion (BIC: Schwarz 1978), $R^2$ adjusted for the degrees of freedom in the model, and Akaike Information Criterion (AIC: Akaike 1974). The use of an AIC and BIC to compare the quasi-Poisson to true likelihood distributions is problematic because these measures of fit rely on the distributional properties of likelihood space (Ver Hoef and Boveng 2007). For this reason, neither the BIC or AIC was calculated for the quasi-Poisson; instead, deviance statistics and model residual analysis were used for comparison. Further, theoretical consideration was given to model predictions given the different weighting schemes used for the negative binomial and quasi-Poisson distributions.

The significance of covariates in the model were evaluated using both the Bayesian p-values calculated using the MGCV package (RCDT 2005) and deviance statistics. These values were used as guidance to determine if covariates were significant at $\alpha = 0.05$. Due to the approximate nature of p-values for GAMs, they were only used as guidance for those model fits. Deviance statistics were used to determine the reduction in deviance as models increased in complexity. For the negative binomial and Poisson distributions, the BIC statistic was used to gauge the tradeoff between reductions in deviance and fewer degrees of freedom. These statistics were not available for the quasi-Poisson, however comparisons within the distribution could be made using GCV scores, with lower values indicating a better fit (Golub et al. 1979).

## 2.4 Results

### 2.4.1 Preliminary Data Analysis

Both the overall number of polygons and total amount of fishing effort (number of hooks) was similar between periods. The number of polygons containing data ranged from 860 in period 1 to 954 for period 4. Total survey and observer effort (number of hooks) between periods did not vary by more than 8%, with period 1 having the least amount of hooks (28,250,730) and period 3 having the highest (34,572,531). Areas with the most observed effort were consistently in the far western GOA, along the shelf break, Cross Sound, and waters off the eastern side of Kodiak Island, west of Yakutat Bay, and Sitka.

Nominal CPUE was highest and most persistent in the eastern GOA, along the coast between Kodiak Island and Cross Sound (Figure 2.4). The highest CPUE values were generally clustered in the nearshore areas between Cross Sound and Yakutat Bay; however, pockets of relatively high CPUE were persistent in western Cook Inlet and off the eastern edge of Kodiak Island (Figure 2.1 and 2.4). Nominal catch rates sharply declined in inside waters, with few spiny dogfish caught in northern Southeastern Alaska. The spatial distribution of CPUE west of Kodiak Island was variable between time periods, with the 1996-1999 time period showing large areas with <0.01 spiny dogfish per hook. The number of polygons with spiny dogfish catches west of Kodiak increased between periods 1 and 3, with most polygons in period 3 containing spiny dogfish catch and CPUE values less than 0.12 spiny dogfish per hook.

The distribution of depth for all polygons was bimodally distributed, with a large peak around 50 m and small peak around 350 m (Figure 2.5). Most fishing effort in deeper regions was associated with the IFQ sablefish fishery, whereas effort in shallower areas reflected a mix of survey and observer data associated with the Pacific cod fishery, as well as vessels likely on mixed halibut/sablefish trips.

Survey data were collected between June and October and fishery data ranged throughout the year depending on the target fishery (Figure 2.6). Most data were collected between April and August. For both periods 2 and 3, the number of observed hauls showed a peak in April and was distributed across the entire GOA. The fishery data also showed distinct patterns depending on the month, with more observed hauls in the western GOA (west of Kodiak Island) between January and March, and October through November. This activity corresponds with the Pacific cod fishery. Fishing effort was widely distributed across the GOA between March and September, during which the IFQ halibut and sablefish fishery are open. In Period 1, fishing effort was widely distributed across the GOA in winter and fall due to the targeting of Pacific cod in the Central GOA.

### 2.4.2 Model Diagnostics

Model convergence was achieved for all models and time periods; however, for the quasi-Poisson and binomial models not all explanatory variables were statistically significant at $\alpha = 0.05$. The tensor product smooth of hooks and longitude in the quasi-Poisson model was significant for only period 3 ($p<0.01$) and period 4 ($p<0.01$). For the negative binomial distribution, the tensor product smooth of longitude and hooks was not significant for period 1 ($p=0.61$). In general, all error distributions showed model 3, which contained the spatial coordinates, bottom depth, and number of hooks, provided the best fit when compared with the other two models. For all error distributions, model 1 performed poorly compared to the other models, as indicated by a low amount of the deviance being explained by the models (Table 2.2).

The addition of the explanatory variable bottom depth and its interaction with hooks (model 2) was significant in all models ($p<0.01$), but generally resulted in small changes in deviance statistics compared with model 1. For the Poisson and negative binomial models, the goodness of fit statistics for periods 2 through 4 were generally worse as model complexity increased from model 1 to model 2. The addition of bottom depth for those periods resulted in small increases in the adjusted $R^2$, but the reduction in the degree of freedoms resulted in an increase in AIC and BIC. The deviance associated with the GLM and GAM quasi-Poisson decreased from model 1 to model 2, and GCV scores showed a small increase between the models for all periods. However, the analysis of residuals indicated a general lack of fit for all periods.

The addition of latitude and longitude as explanatory variables dramatically improved the goodness of fit for all models. In all periods except period 3 of the negative binomial model, the AIC, deviance, and adjusted $R^2$ indicated an improvement in fit of model 3 over model 2 (Table 2.2). This was particularly dramatic for the quasi-Poisson GAM, which showed large decreases in the GCV score. The effective degrees of freedom dramatically increased with the addition of the latitude and longitude smoothing parameters. The large effective degrees of freedom for the spatial smoothing parameter indicated the flexibility afforded to the spatial covariates and smoothing. The spatial smoothing also improved the distribution of residuals, but the Poisson and quasi-Poisson models both tended to overestimate spiny dogfish counts while the negative binomial models tended to underestimate spiny dogfish counts. The other covariates in model 3 across all probability distributions generally had much less flexibility as indicated by the smaller residual degrees of freedom (Table 2.2).

Based on the goodness of fit statistics and residual analysis, the covariates in model 3 provided the best fit, but there were large differences in fit between probability distributions (Figure 2.7). The GLM and negative binomial models had the worst fits, with a lower amount of deviance explained and poor fit to residual statistics. The amount of deviance explained between the quasi-Poisson and Poisson GAM was similar, with the Poisson generally having a higher amount of explained deviance for each time period, which would be expected with a more flexible model and higher effective degrees of freedom.

Analysis of model residuals showed that the Poisson tended toward large overestimation of spiny dogfish counts for each time period, which resulted in a long positive tail in the residual distribution. The quasi-Poisson model also tended towards overestimation, but to a much less extent than the Poisson error structure. The Poisson model also tended to be sensitive to the number of basis dimensions selected for the thin plate regression spline, choosing models with a very high EDF. While this in itself does not indicate a poor fit, the spatial components of the model were likely selecting a large basis dimension to compensate for the over-dispersion in spiny dogfish counts. The dispersion parameter for the Poisson model is equal to 1, while for the quasi-Poisson model the parameter is treated as unknown. The selected scale parameters all indicated over-dispersion and were 138 for period 4, 66 for period 3, 44 for period 2, and 34 for period 1 (Table 2.3). The overdispersion allowed for a better characterization of the non-parametric spatial effects and greatly improved residual distribution.

The binomial model explained less than half of the null deviance for all time periods and generally did a poor job fitting in the western GOA. The adjusted $R^2$ values for this model were low, explaining <50% of the model variation (Table 2.4). However, all explanatory variables were statistically significant ($p < 0.01$), with the exception of the tensor product smooth of the number of hooks and bottom depth in period 2, ($p = 0.06$). As with the other error structures, the spatial smoothing component had the largest estimated degree of freedom, which suggests the spatial smoothing had a large degree of flexibility relative to other smoothing variables and accounted for much of the modeled variation.

### 2.4.3 Quasi-Poisson Explanatory Variables

The tensor product smooth of hooks and longitude was significant for period 3 and period 4, with both periods showing similar spatial trends (Figure 2.8). The smooth showed a general trend towards a neutral or positive effect as the number of hooks fished increased, and negative smoothing effects were observed for the eastern GOA, between Prince William Sound and Yakutat Bay. Positive smoothing was observed for areas between the Aleutian Islands and Kodiak Island, and the inside waters of southeastern Alaska. These smoothing gradients generally correspond to areas of high or low spiny dogfish catch, with negative smoothing corresponding to areas of higher catch and positive smoothing to areas of lower catch. A negative smoothing gradient suggests that, compared to all other longitude values and for a given hook value, the non-linear effect was negatively associated with increased spiny dogfish counts, giving hooks less of an impact on the number of dogfish predicted by the model.

Smoothing effects of bottom depth fished and the number of hooks showed a sharp decline around 200 m and at a smaller number of hooks (Figure 2.9). The steepness of the smoothing gradient suggested a strong negative effect on spiny dogfish counts as both depth and the number of hooks decreased. In both period 1 and 3, the smoothing function generally showed little change due to bottom depth beyond

3,000 hooks, indicating that the smoothing effect of fishing depth was much less at higher hook counts. An important feature of the smoothing term was a lag in the smoothing effect between 1 and 100 meters, suggesting a greater positive effect on spiny dogfish counts at those depths when compared with other depths.

For all time periods, the thin plate regression spline smooth of latitude and longitude showed a general positive smoothing effect for the eastern GOA, with negative to neutral smoothing for the inside waters of northern inside waters of southeastern Alaska, western GOA, and deeper waters on the continental slope (Figure 2.10). In all periods, pockets of positive smoothing on spiny dogfish counts were also observed on the southwestern portion of Kodiak Island as well as the western side of Cook Inlet. Period 3 had less of a west to east gradient in the GOA. This change corresponded with a general increase in the distribution and number of spiny dogfish caught in the western GOA. Further, period 2 showed a specific cluster in the western GOA, which suggested an increase in the spatial smooth when compared with period 1, but overall was less when compared with period 3. The model for all time periods showed the same east to west tendencies in the smoothing gradient and patchy areas of positive effects on spiny dogfish catch in western GOA as well as some very high positive values in the central GOA. Finally, all models showed a fairly strong gradient in southeastern Alaska, with smoothing values increasing towards the outside coast and south. This pattern generally followed nominal CPUE trends.

### 2.4.4 Binomial Explanatory Variables

The TPRS spatial smooth for the binomial model generally captured both temporal and spatial changes reflecting the presence or absence of spiny dogfish. The raw count data showed a general trend of more cells containing spiny dogfish in the eastern GOA through time. The binomial model reflected this trend, showing a larger positive smoothing effect in the western GOA, particularly for waters between Cross Sound and Prince William Sound (Figure 2.11). In addition, the absence of spiny dogfish counts in northern half of the inside waters of Southeast Alaska was also reflected as a strong negative smooth for that area.

The spatial smoothing variable also reflected a general increase in the number of polygons containing spiny dogfish in the western GOA (Figure 2.4). Comparison of smoothing in period 1 and 3 in the western GOA shows the amount of negative spatial smoothing relative to other areas in the GOA decreased. This corresponds with a general increase in the predicted probability of counts occurring in the western GOA from period 1 to period 3 (Figure 2.12). However, in the Yakutat Bay region in period 2, the model tended to show a higher probability on the shelf break relative to the inshore areas, which is opposite of the raw count data. In addition, the model tended to overestimate the probabilities for spiny dogfish in regions to the north and west of Kodiak, showing high probabilities in areas with no spiny dogfish catch. However, the model captured the overall trend of higher probabilities of encounter in the central and western GOA.

Besides the spatial smoothing components of latitude and longitude, tensor product smooths for bottom depth and hooks, bottom depth and longitude, and hooks at longitude were significant ($p<0.01$). Decreasing depth and increasing number of hooks generally showed a positive effect on spiny dogfish count. In period 2 there was a strong positive effect observed between 50 and 100 m. Bottom depth and longitude showed that as depth increased across all longitude values, the smoothing effect went from positive to negative, indicating the number spiny dogfish predicted by the model declined at deeper depths. The exception to this trend occurred in depths between 1 and 100 m, where a localized positive smooth occurred in the region off Yakutat for period 1, period 3, and period 4, and the central GOA for period 3. The effects of the number of hooks and longitude on spiny dogfish counts were negative at longitude values between -150° W and -145° W, corresponding to the GOA area between Prince William Sound and outer coast of southeastern Alaska. In the western GOA, the effect of hooks and longitude changed between period 1 and period 2, with a greater positive effect in period 3 for medium to high hook counts.

## 2.5 Discussion

Our models successfully identified areas in the GOA where spiny dogfish are particularly vulnerable to fishing mortality; however, data over-dispersion proved difficult to model and all models tended to overestimate the number of spiny dogfish in areas with very low counts. The quasi-Poisson model was the best model and accommodated some dispersion. The large difference in fit between the negative binomial and quasi-Poisson was due to the differences in the weighting of the P-IRLS.

The negative binomial distribution places more weight on sites with smaller counts than the quasi-Poisson, which resulted in large counts being severely underestimated and general lack of fit. For a global estimate of spiny dogfish, the quasi-Poisson provides a good fit; however, for areas with small counts of spiny dogfish, the difference in weighting results in a slightly worse fit. However, even more weight was placed on large sites for the quasi-Poisson, the model fit for areas with low spiny dogfish count was only slightly worse, while for medium to large values it was dramatically better. We were particularly interested in the overall pattern of dogfish catch for the GOA, which was best estimated with the quasi-Poisson due to its ability to weight smaller sites less and accurately fit to medium and large sites. Further, because the overestimation on small sites was generally small, comparison with large and medium sites produced meaningful results.

Overdispersion can be caused by many factors including clustering of animals, animals having individual responses to covariates, and variables that are not measured which could result in model misspecification (Eberhardt 1978, Zurr et al. 2009). The schooling behavior of spiny dogfish is well documented and the model results are consistent with this behavioral characteristic. Model results show a patchy distribution of spiny dogfish, which causes overdispersion due to clustering of observations and potentially a large number of zero observations. Finally, there may be latent covariates not included in the model that influence the distribution of spiny dogfish throughout the GOA. These unknown covariates include seasonal changes in the distribution of spiny dogfish, changes in the underlying spiny dogfish population size, migration and immigration, changes in prey species distribution, unknown environmental factors, and interactions between these variables. All these processes are likely to be occurring, but their extent is unknown.

The lack of observer data in nearshore areas commonly fished by unobserved longline vessels required the use of survey information as a proxy for unobserved fishing vessels. This assumption is problematic given that the IPHC survey is highly standardized so fishing power is assumed the same in all areas and years (Clark and Hare 2006). However, differences in fishing power between a standardized survey and longline vessels in the fishery may occur, which would lead to an inaccurate spatial assessment of the vulnerability of spiny dogfish to the fishery. This is an inherent weakness of the analysis, but the differences may not be large, given that the IPHC survey uses similar gear configurations to those used in the fishery and the survey occurs in similar areas and times as the fishery (except Pacific cod). Regardless of whether survey or fishery information is used, the overall ability of longline vessels to catch spiny dogfish could be underestimated because fishing is not being optimized for the capture of spiny dogfish. In the case of fishery dependent data, hooked spiny dogfish displace the catch of more valuable species and they depredate gear, thus fishermen will try to avoid catching spiny dogfish.

Much resolution was lost due to the aggregation of the vessel-specific dataset into time periods and 20-$km^2$ spatial units. The temporal aggregation is especially problematic given that the distribution of spiny dogfish may change through time and within a period. Thus, if the goal of the study had been to standardize CPUE as an index of abundance in a stock assessment model, the temporal methodology employed would not be appropriate because it would not detect yearly changes in abundance, nor would it account for gear selectivity within the spiny dogfish population.

Large yearly changes in the overall spiny dogfish abundance in the GOA are unlikely given the low fecundity and longevity of species, but localized changes are possible due to immigration or emigration. Significant regional effects at the Federal reporting area level in the central and eastern GOA despite small yearly changes in overall CPUE have been demonstrated (Rice 2007). Our modeling results showed that there were differences in the western GOA between time periods, indicating that spiny dogfish were more evenly distributed in period 3. Both the logit and quasi-Poisson models showed this trend, with the smoothing effects on the probability of capture and counts increasing through time. The eastern GOA showed very strong positive smoothing between Kodiak and Cross Sound for all time periods. The smoothing effects were particularly strong, in all periods, for nearshore waters between Yakutat Bay and Prince William Sound, and southwestern Cook Inlet. These areas also corresponded with the highest nominal CPUE values and probability of capture as suggested by the logit model. Together, this region contains the highest abundance of spiny dogfish vulnerable to longline gear, but nothing is known about the underlying population demography and the selectivity of spiny dogfish to longline gear. Thus, there could be areas of high concentrations not represented in this analysis due to gear selection alone.

The lack of survey and fishery data in the winter and late fall months prevented interpretation of seasonal shifts in spiny dogfish distribution. In waters off Oregon, Washington, and British Columbia, spiny dogfish populations show tendencies for both site fidelity and migration (McFarlane and King 2003; Taylor 2008). In the inside waters Puget Sound and Strait of Georgia the spiny dogfish populations are thought to be year round residents, unlike spiny dogfish occurring on the outer coast, which likely move south in the winter months and north in spring months (Taylor 2008). Spiny dogfish occurring in waters off Alaska are poorly understood in regard to seasonal movements, but available size distributions and catch rates seem to indicate that dogfish tend to occur offshore in winter, migrate inshore in spring, and return offshore in late fall (Tribuzio 2010). Other migratory species occurring in the GOA, such as salmon shark *(Lamna ditropis)*, and teleost species such as Pacific halibut, show strong annual migratory patterns. Recent tagging revealed that a portion of the salmon shark population moves to southern waters during the winter months (Hulbert et al. 2005, Weng et al. 2005). Halibut move from inshore summer feeding areas to offshore spawning grounds, on the edge of the continental shelf, to spawn during the winter months (Seitz et al. 2005). In addition, Pacific halibut also have a strong west to east migratory pattern, with a portion of the population moving east as they near maturity in a counternatant pattern in the opposite direction of larval drift. While a core component of these migrations is likely a result of reproductive cycles, there is also a strong seasonality of prey sources in Alaska that drive species migrations. Based on diet analysis, Tribuzio (2010) hypothesized that in early spring the abundance of spiny dogfish increases in inshore waters coincident with forage fish spawning runs such as capelin (*Mallotus villosus*). They tend to remain inshore throughout the summer and into the fall, adding larger prey items (such as rockfish and octopus) to their diets as summer progresses. During the winter, many prey move to deeper, offshore waters, but the extent of winter-time feeding and the behavioral response of spiny dogfish to offshore prey migrations are uncertain.

Our analysis showed a dearth of spiny dogfish in inside waters of northern Southeast Alaska. With the exception of the few data points in southern Chatham Strait, the inside waters of northern Southeast Alaska was the only region of the GOA that showed a consistent lack of spiny dogfish for all periods. Many species that are abundant in the outside waters of northern Southeast Alaska are all but absent in inside waters (Hubartt et al. 2001). The lack of dogfish in the northern inside waters is likely a year-round pattern and not a result of availability of survey data during the spring and summer only. Sportfishing creel survey and anecdotal information from commercial fishermen also suggest that spiny dogfish are not present in large numbers in early fall in northern Southeast Alaska.

Future target fisheries for spiny dogfish, if they are to develop, are likely to develop in areas with the highest concentrations. The magnitude of spatial smoothing is relative and differences in the smoothing parameter across the GOA demonstrate spatial heterogeneity in dogfish counts. Our results suggest these areas could range from the outer coast of Southeast Alaska to Cook Inlet, with the areas of the highest concentrations off Yakutat Bay. Between 1996 and 2008 there was increased positive spatial influence in the western GOA and less overall spatial heterogeneity in the GOA. While this may indicate an increase in the size of the dogfish population, it may also be due to changes in the distribution of dogfish across the GOA. The changes in distribution are small relative to the entire GOA, with the core of the population remaining east of Kodiak for all time periods examined.

The size of spiny dogfish caught in a directed fishery is an important consideration from both a fishery management and stock assessment perspective. Larger spiny dogfish, which are often mature females, generally bring higher prices (Billingsgate 2005). Unfortunately size composition information is not currently available from observers to assess the selectivity of spiny dogfish catch and how this would relate to the expected catch composition for longline vessels. Regardless of whether a fishery develops, size information is critical for understanding the gear selectivity of the longline fleet and its impact on the spiny dogfish population, both locally and regionally.

Model results also do not offer insights into seasonal migration nor do they necessarily indicate changes in underlying population abundance. Thus, further investigation in the underlying population is needed to determine the cause of these temporal changes, and the extent to which within-year variability influences each time period. The models indicate that the eastern GOA is an area of core abundance for spiny dogfish, but further work is needed to substantiate population structure. At the very least, these areas are likely critically important to the spiny dogfish population structure and the modeling results provide an important starting point for future population research on a very poorly understood species in Alaska.

Finally, the lack of observer data in the nearshore areas of the eastern GOA could present significant data estimation issues given the highest concentrations of dogfish occur in this area and there is considerable commercial fishing effort. The primary fisheries of concern are the unobserved fisheries that operate in that area, including the halibut IFQ fishery, the set-net salmon fishery off Yakutat, the gill net salmon fishery in the Copper River Delta, and potentially salmon troll fisheries that operate along the entire coast. The halibut IFQ fishery may be a substantial source of unestimated mortality given that it operates nearly year round using similar fishing methods to the survey analyzed here. Information collected by at-sea observers is spatially aggregated across potentially dissimilar areas to estimate total bycatch in federal groundfish fisheries. This is necessary because some vessels are not required to carry observers or are required to carry observers on 30% of their fishing trips. The patchy distribution of dogfish may create estimation bias if observer information is applied to non-observed vessels fishing in areas with dogfish catch different from the bycatch rates derived from observer information.

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## 2.8 Tables

Table 2.1 The average number of vessels and catch (t) of spiny dogfish by catcher processors (CPs) and catcher vessels (CVs) in the GOA between 2003 and 2007. The observed catch only includes catch from sampled hauls. Motherships are not included because they are only involved with processing and not harvesting.

| | Vessels | | | Observed Catch | | All Catch | | Total |
|---|---|---|---|---|---|---|---|---|
| | Total Count | Sector (%) | Observed (%) | Catch (t) | Sector (%) | Catch (t) | Sector (%) | Catch Observed (%) |
| CP | 21 | 3 | 90 | 5,155 | 61 | 6,792 | 32 | 76 |
| CV | 812 | 97 | 5 | 2,030 | 39 | 21,024 | 68 | 10 |

Table 2.2 Summary statistics for GAM and GLM models by time period and associated summary statistics including the residual model degree of freedom (Res d.f.), model deviance (Dev), quasi-Poisson model (QP), negative binomial model (NB), Poisson model (P), Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and adjusted estimated degrees of freedom (Adj-$R^2$).

| | Model | Adj-$R^2$ | AIC | BIC | Res d.f | Dev. | Null Dev | Δ Dev |
|---|---|---|---|---|---|---|---|---|
| GAM-QP | 1 | 0 51 | - | - | 855 | 130,941 | 266,362 | -135,421 |
| 1996-1999 | 2 | 0 60 | - | - | 844 | 105,450 | 266,362 | -25,491 |
| | 3 | 0.92 | - | - | 759 | 21,308 | 266,362 | -84,142 |
| | | | - | - | | | | |
| | 1 | 0 21 | - | - | 873 | 267,193 | 336,445 | -69,252 |
| 2000-2003 | 2 | 0.34 | - | - | 865 | 221,996 | 336,445 | -45,197 |
| | 3 | 0.91 | - | - | 726 | 31,708 | 336,445 | -190,288 |
| | | | - | - | | | | |
| | 1 | 0.26 | - | - | 853 | 363,182 | 488,882 | -125,700 |
| 2004-2008 | 2 | 0 31 | - | - | 847 | 335,175 | 488,882 | -28,007 |
| | 3 | 0.91 | - | - | 675 | 44,255 | 488,882 | -290,920 |
| | | | - | - | | | | |
| | 1 | 0 29 | - | - | 946 | 664,984 | 942,729 | -277,745 |
| 1996-2008 | 2 | 0.38 | - | - | 936 | 585,412 | 942,729 | -79,572 |
| | 3 | 0 88 | - | - | 809 | 111,643 | 942,729 | -473,769 |
| GAM-NB | 1 | 0.12 | 15,938 | 15,973 | 859 | 844 | 1026 | |
| 1996-1999 | 2 | 0 28 | 15,698 | 15,771 | 851 | 845 | 1178 | |
| | 3 | 0 70 | 15,541 | 15,874 | 796 | 854 | 2871 | |
| | 1 | 0.12 | 16,556 | 16,601 | 873 | 943 | 1076 | |
| 2000-2003 | 2 | 0.23 | 16,560 | 16,637 | 867 | 941 | 1220 | |
| | 3 | 0 69 | 16,005 | 16,504 | 779 | 936 | 3,040 | |
| | 1 | 0 15 | 16,788 | 16,833 | 852 | 1027 | 1204 | |
| 2004-2008 | 2 | 0 22 | 16,661 | 16,725 | 848 | 1021 | 1306 | |
| | 3 | 0.70 | 16,364 | 16,860 | 763 | 985 | 3214 | |
| | 1 | 0.14 | 19,625 | 19,669 | 946 | 1125 | 1302 | |
| 1996-2008 | 2 | 0 26 | 19,600 | 19,714 | 932 | 1126 | 1528 | |
| | 3 | 0.64 | 18,931 | 19,479 | 842 | 1154 | 3198 | |
| GAM-P | 1 | 0 51 | 15,334 | 15,387 | 855 | 129,256 | 266,362 | -137,106 |
| 1996-1999 | 2 | 0 61 | 15,252 | 15,374 | 840 | 105,226 | 266,362 | -24,030 |
| | 3 | 0.94 | 14,242 | 15,409 | 668 | 16,143 | 266,362 | -89,083 |
| | 1 | 0 24 | 16,506 | 16,559 | 872 | 254,599 | 336,445 | -81,846 |
| 2000-2003 | 2 | 0 35 | 16,509 | 16,633 | 857 | 217,837 | 336,445 | -36,762 |

Table 2.2 continued

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 3 | 0 93 | 15,162 | 16,343 | 685 | 22,189 | 336,445 | -195,648 |
| | 1 | 0 3 | 16,432 | 16,484 | 850 | 340,365 | 488,882 | -148,517 |
| 2004-2008 | 2 | 0 36 | 16,626 | 16,750 | 835 | 312,243 | 488,882 | -28,122 |
| | 3 | 0 93 | 15,116 | 16,291 | 664 | 35,758 | 488,882 | -276,485 |
| | 1 | 0 34 | 19,254 | 19,307 | 944 | 625,055 | 942,729 | -317,674 |
| 1996-2008 | 2 | 0 41 | 19,258 | 19,461 | 913 | 552,549 | 942,729 | -72,506 |
| | 3 | 0 91 | 17,488 | 18,688 | 757 | 85,684 | 942,729 | -466,865 |
| GLM-QP | 1 | 0 25 | - | - | 863 | 19,885 | 266,362 | -246,477 |
| 1996-1999 | 2 | 0 47 | - | - | 861 | 141,248 | 266,362 | 121,363 |
| | 3 | 0 74 | - | - | 855 | 68,221 | 266,362 | -73,027 |
| | 1 | 0 14 | - | - | 880 | 290,425 | 336,445 | -46,020 |
| 2000-2003 | 2 | 0 23 | - | - | 878 | 257,788 | 336,445 | -32,637 |
| | 3 | 0 62 | - | - | 872 | 128,424 | 336,445 | -129,364 |
| | 1 | 0 22 | - | - | 858 | 380,745 | 488,882 | -108,137 |
| 2004-2008 | 2 | 0 27 | - | - | 856 | 358,596 | 488,882 | -22,149 |
| | 3 | 0 53 | - | - | 850 | 229,553 | 488,882 | -129,043 |
| | 1 | 0 22 | - | - | 952 | 734,157 | 942,729 | -208,572 |
| 1996-2008 | 2 | 0 3 | - | - | 950 | 659,262 | 942,729 | -74,895 |
| | 3 | 0 62 | - | - | 944 | 350,240 | 942,729 | -309,022 |

Table 2.3 Generalized Cross Validation (GCV) scores and scale of the over-dispersion parameter by model and time period for the quasi-Poisson distribution in the GAM models.

| Time period | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | GCV | Scale | GCV | Scale | GCV | Scale |
| 1996-1999 | 156.2 | 153 | 131 | 125 | 38 | 34 |
| 2000-2003 | 311.4 | 306 | 266 | 257 | 64 | 44 |
| 2004-2008 | 432.4 | 426 | 407 | 396 | 106 | 66 |
| 1996-2008 | 714.8 | 703 | 647 | 625 | 189 | 138 |

Table 2.4 Goodness of fit statistics for the GAM binomial regression model with logit link. Model covariates were the same as those used in model 3 in Table 2.1.

| Time period | Adjusted $R^2$ | Deviance | Null Deviance | Null d.f | Res. d.f |
|---|---|---|---|---|---|
| 1996-1999 | 0.40 | 709 | 1,186 | 865 | 823 |
| 2000-2003 | 0.48 | 601 | 1,157 | 882 | 808 |
| 2004-2008 | 0.48 | 483 | 928 | 860 | 820 |
| 1996-2008 | 0.39 | 668 | 1,087 | 954 | 920 |

## 2.9 Figures

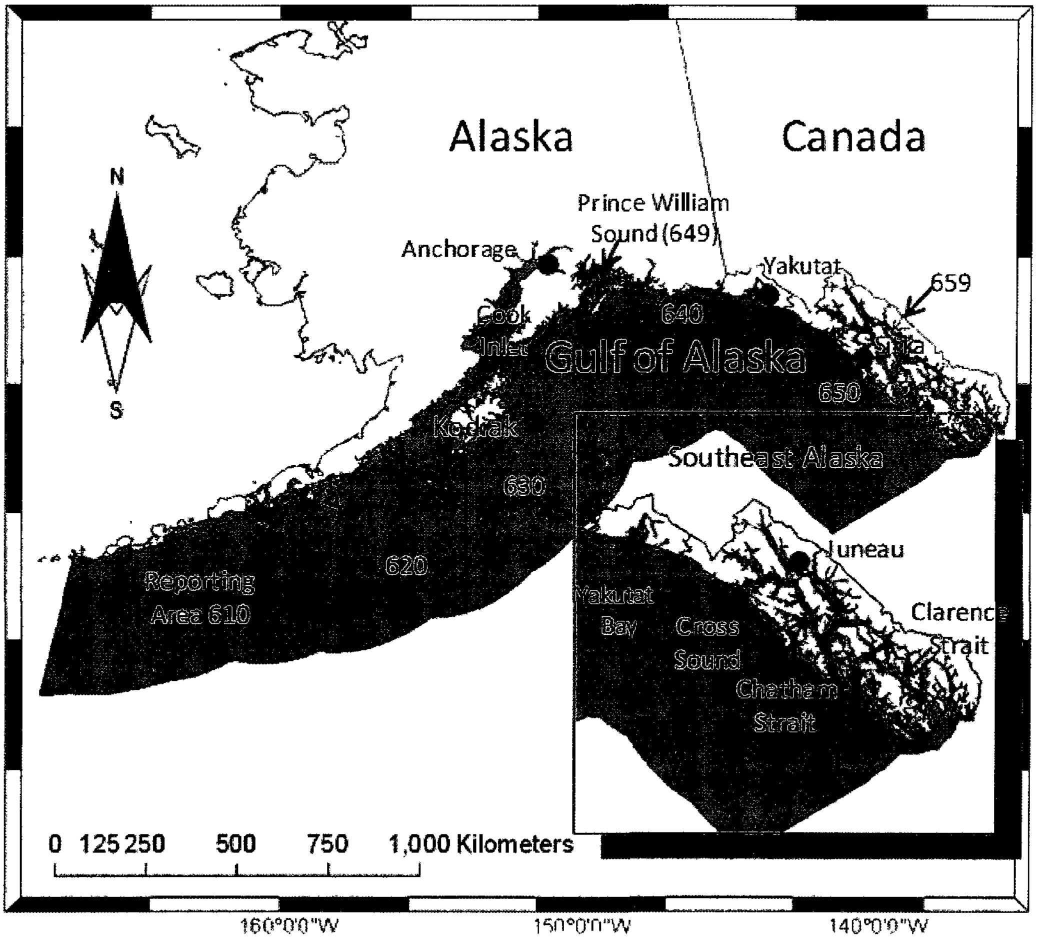


Figure 2.1. Map of the Gulf of Alaska showing fishing and numbered reporting areas referenced in the text.

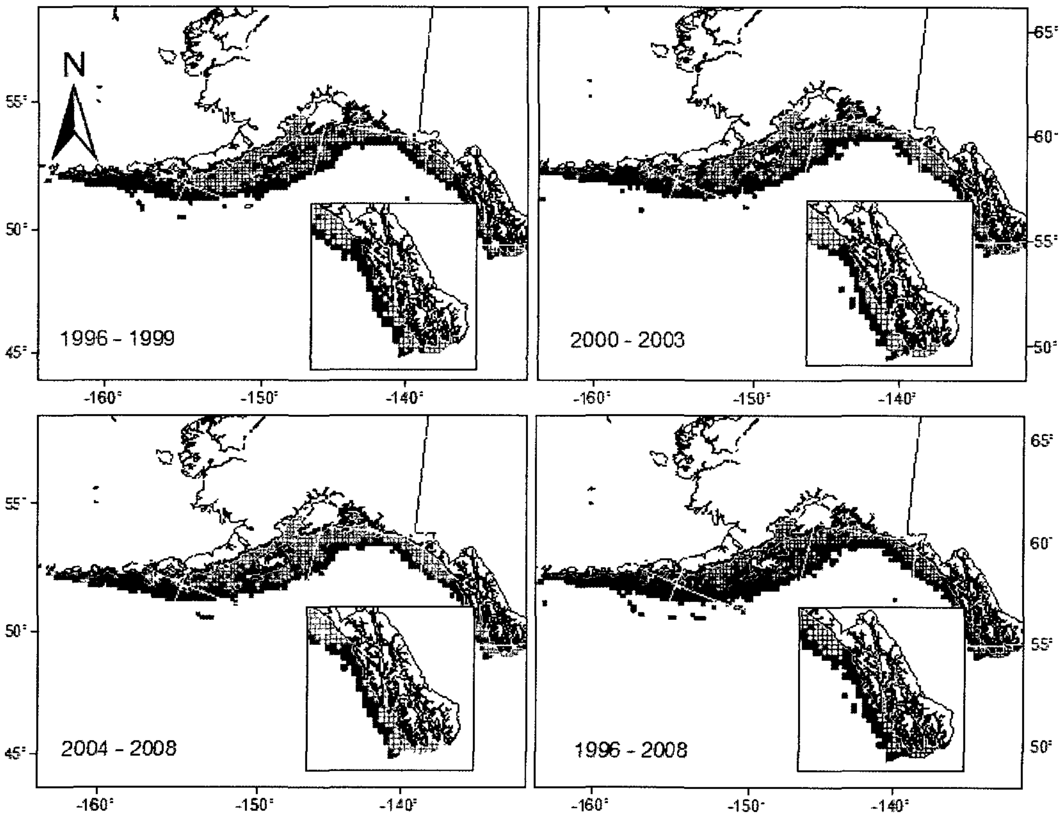


Figure 2.2. Spatial distribution of survey and observer information by 20 $km^2$ polygons. Dark grey indicates observer records were used to summarize data in the polygon. Light grey indicates that only IPHC or Chatham Strait survey records (only) were summarized in the polygon.

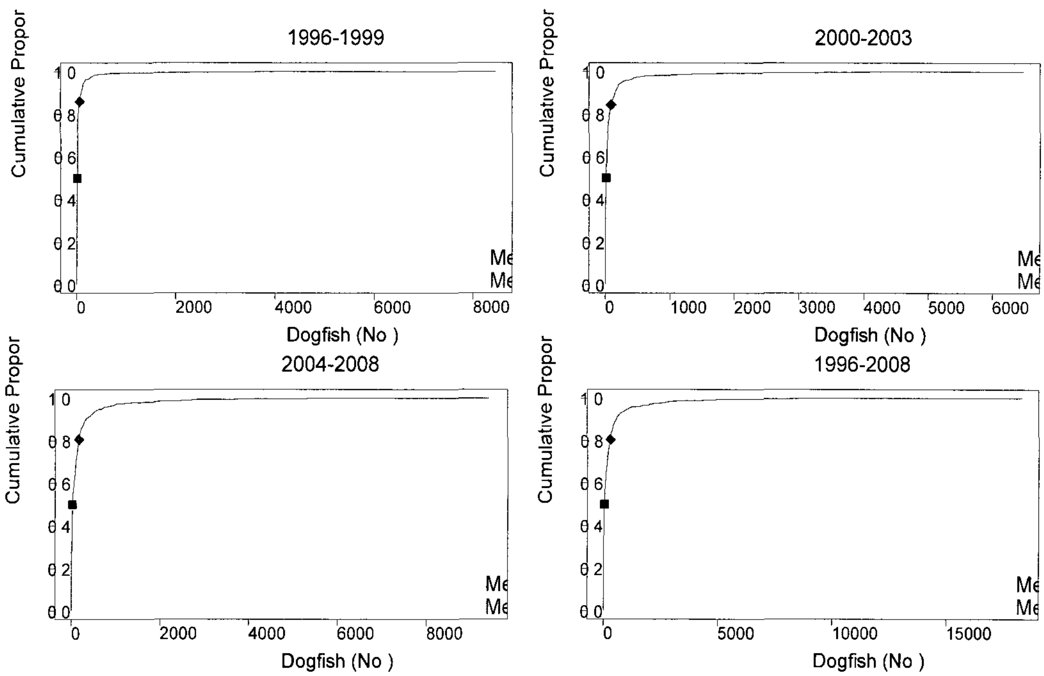


Figure 2.3. Distribution of dogfish by time period. The square point represents the median, the diamond represents the mean, and the solid line indicates the cumulative frequency of dogfish counts across all polygons within a time period.

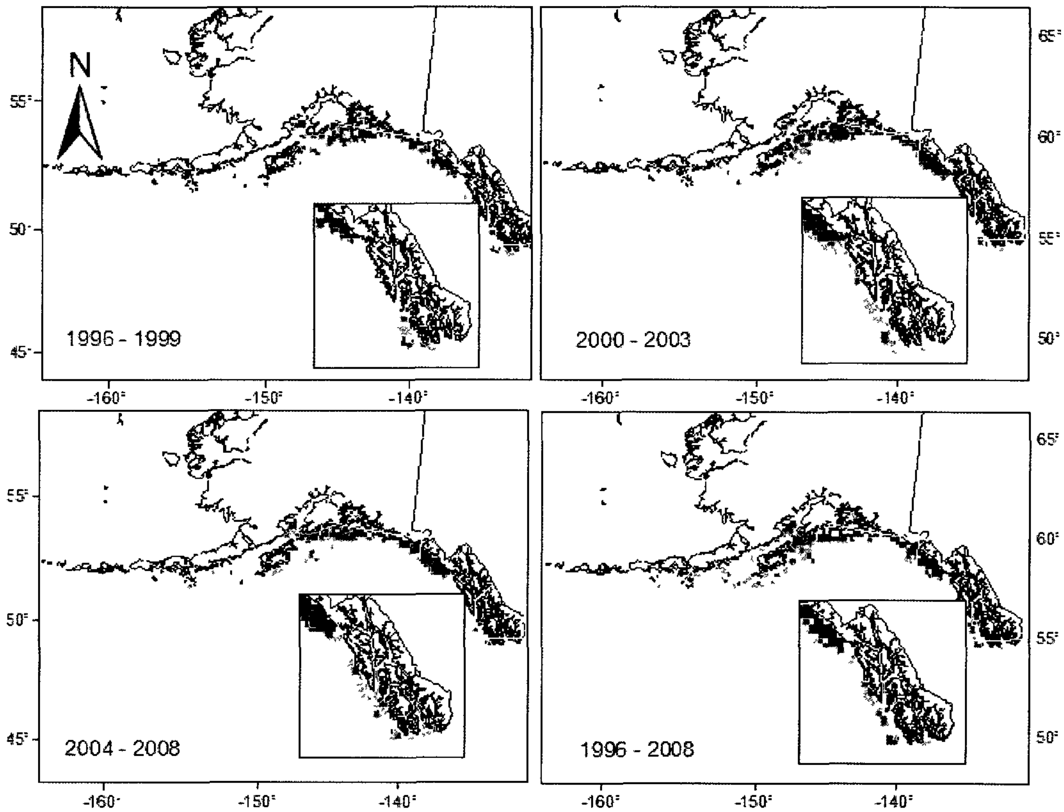


Figure 2.4. Nominal CPUE values by 20 $km^2$ polygons. White colored cells indicate no dogfish were caught during the time period, with darker colors indicating increasing values of CPUE.

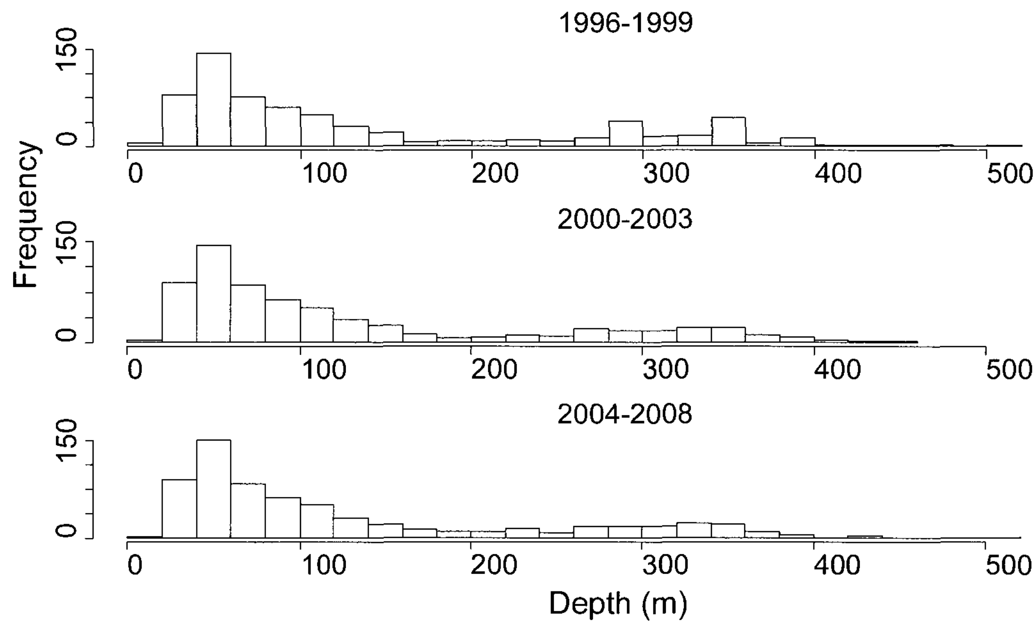


Figure 2.5. The depth distribution for polygons within the three modeled time periods by 50-m increments.

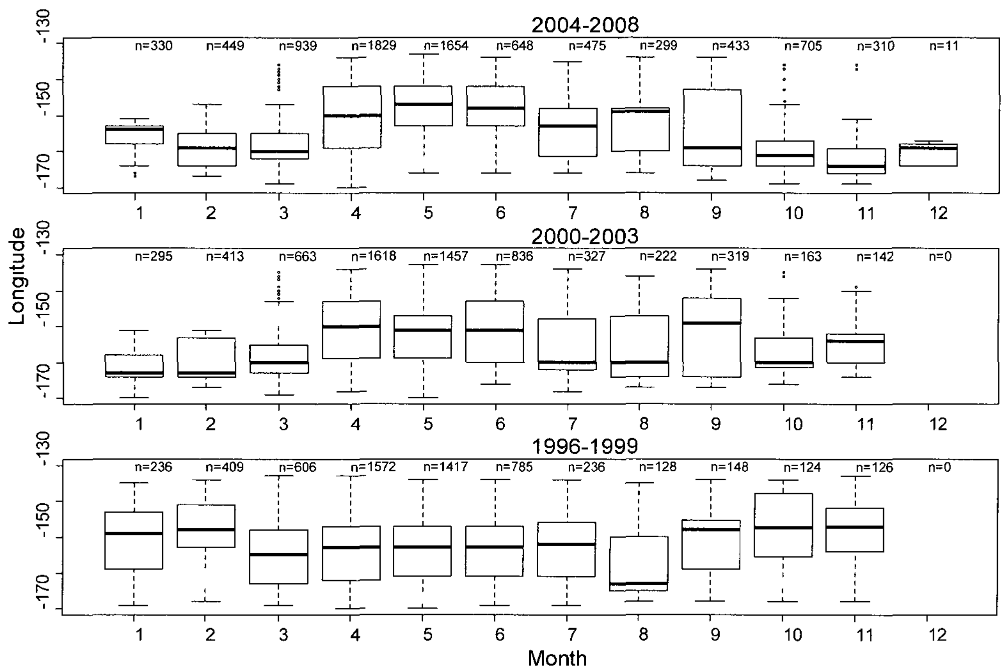


Figure 2.6. The number of observed hauls across months and within each time period. The box encompasses 50% of the data and the median is indicated by a dark horizontal bar. The bars on the outside of the box indicate either 2 standard errors or the extent of the data if no outliers are present.

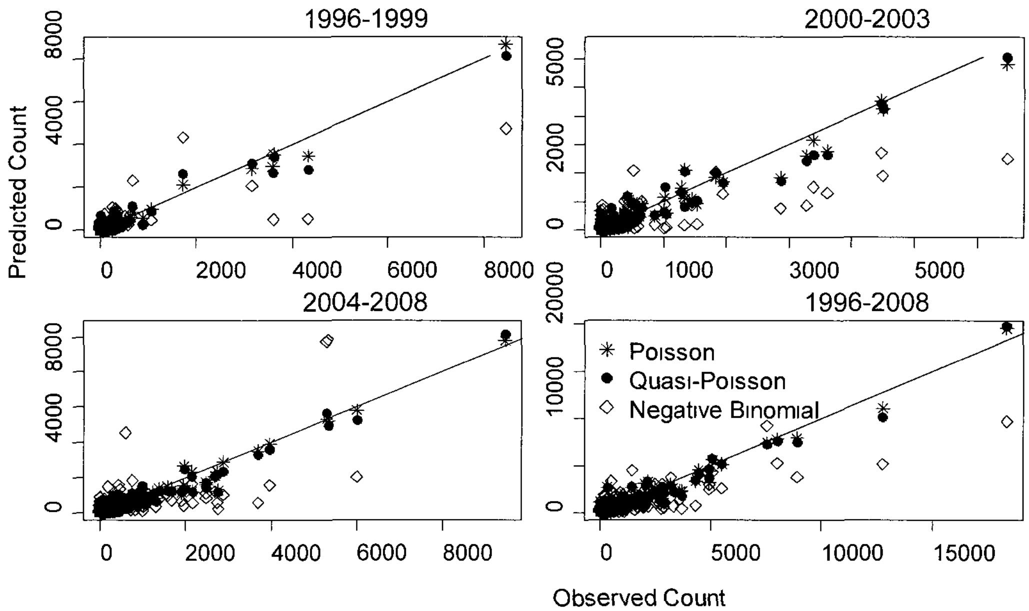


Figure 2.7. Observed versus predicted counts of dogfish for model 3 by period for the Poisson, negative binomial, and quasi-Poisson GAM models.

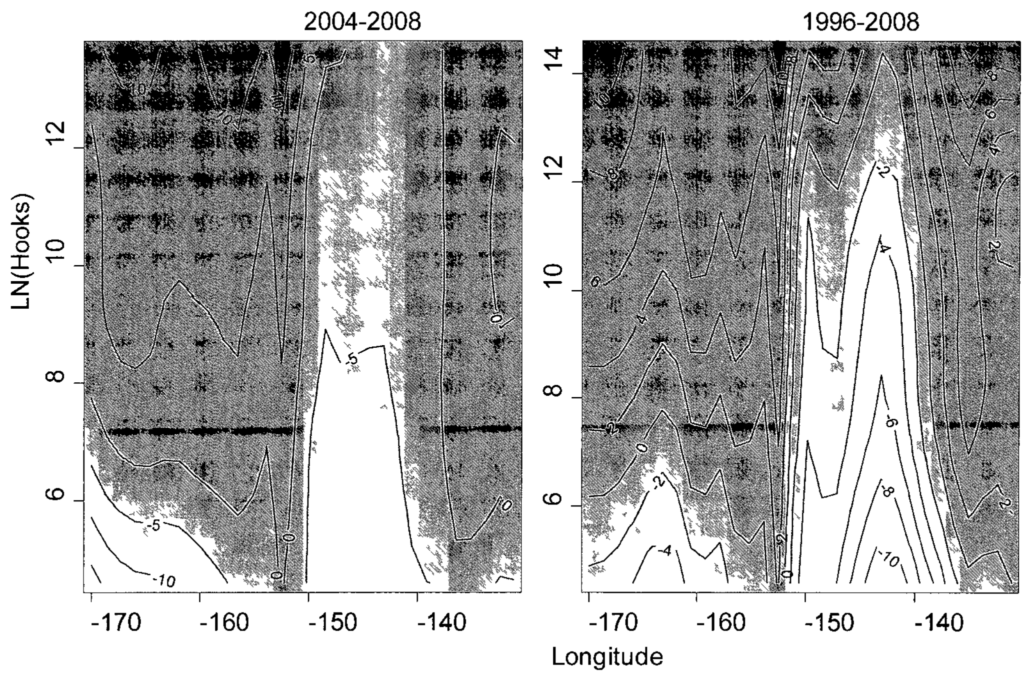


Figure 2.8. Tensor product smooth of the natural log of the number of hooks and longitude for the quasi-Poisson GAM regression model. Note smoothing isotherms are arranged so darker colors indicate a greater positive smooth.

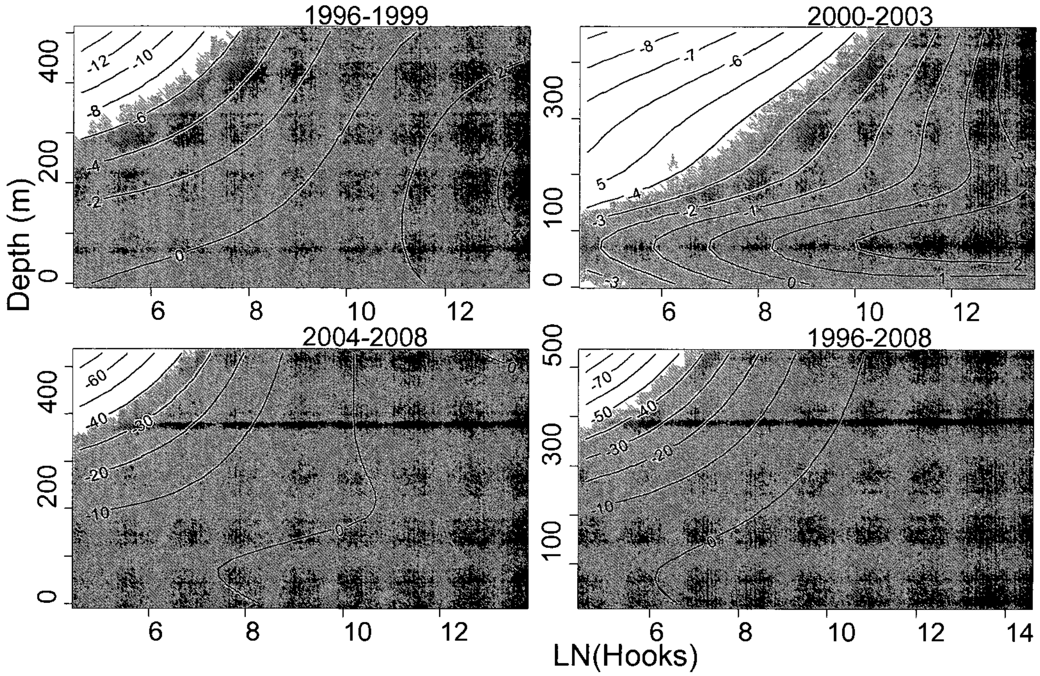


Figure 2.9. Tensor product smooth of bottom depth and hooks for the quasi-Poisson GAM regression model. Note smoothing isotherms are arranged so darker colors indicate a greater positive smooth.

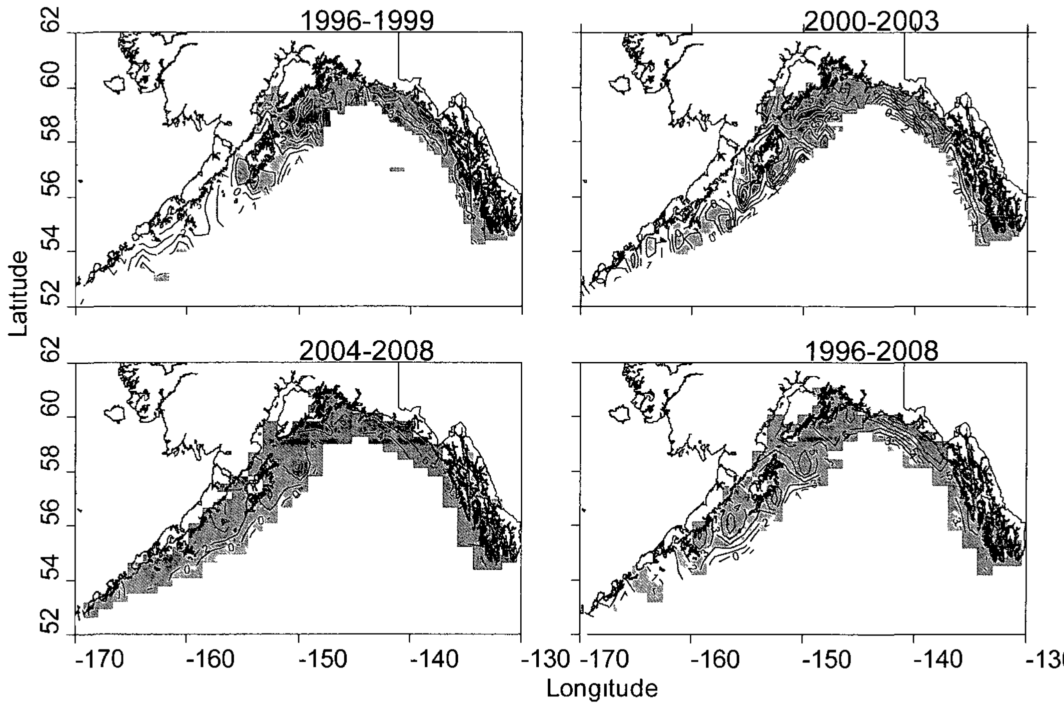


Figure 2.10. Thin Plate Regression Spline smooths for latitude and longitude of the quasi-Poisson GAM regression model by time period. Smoothing isotherms are arranged so darker colors indicate a greater positive smooth as the color darkens.

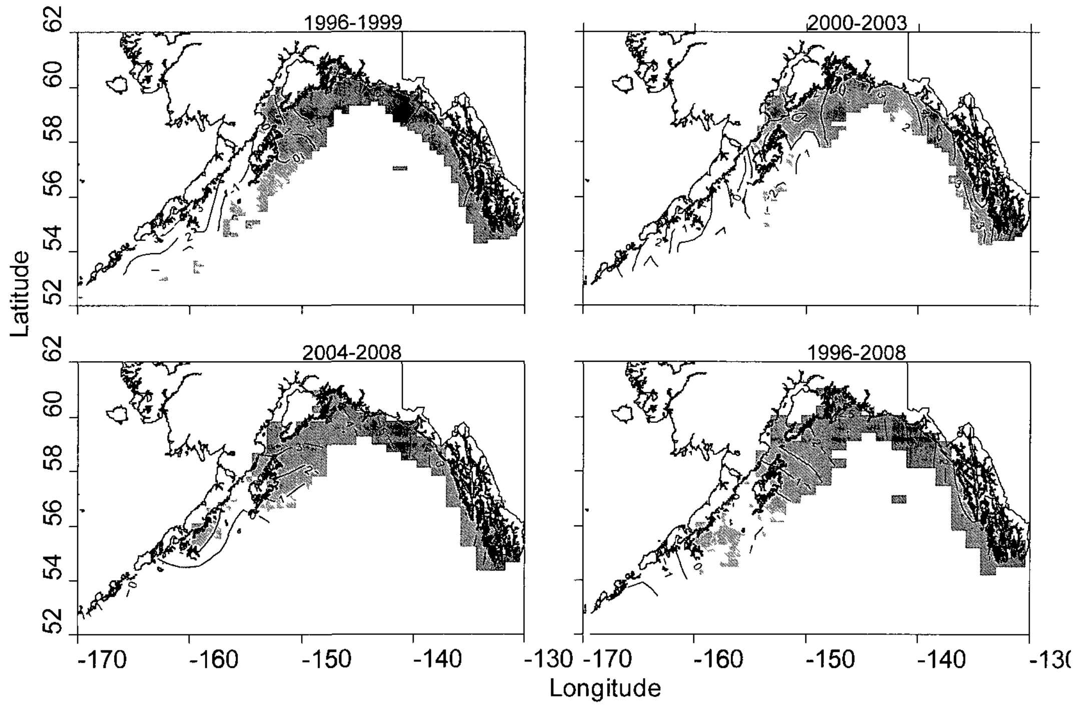


Figure 2.11. Thin Plate Regression Spline smooth for spatial coordinates of the GAM binomial probability model. Darker colors indicate a higher positive spatial smooth for the Thin Plate Regression Spline.

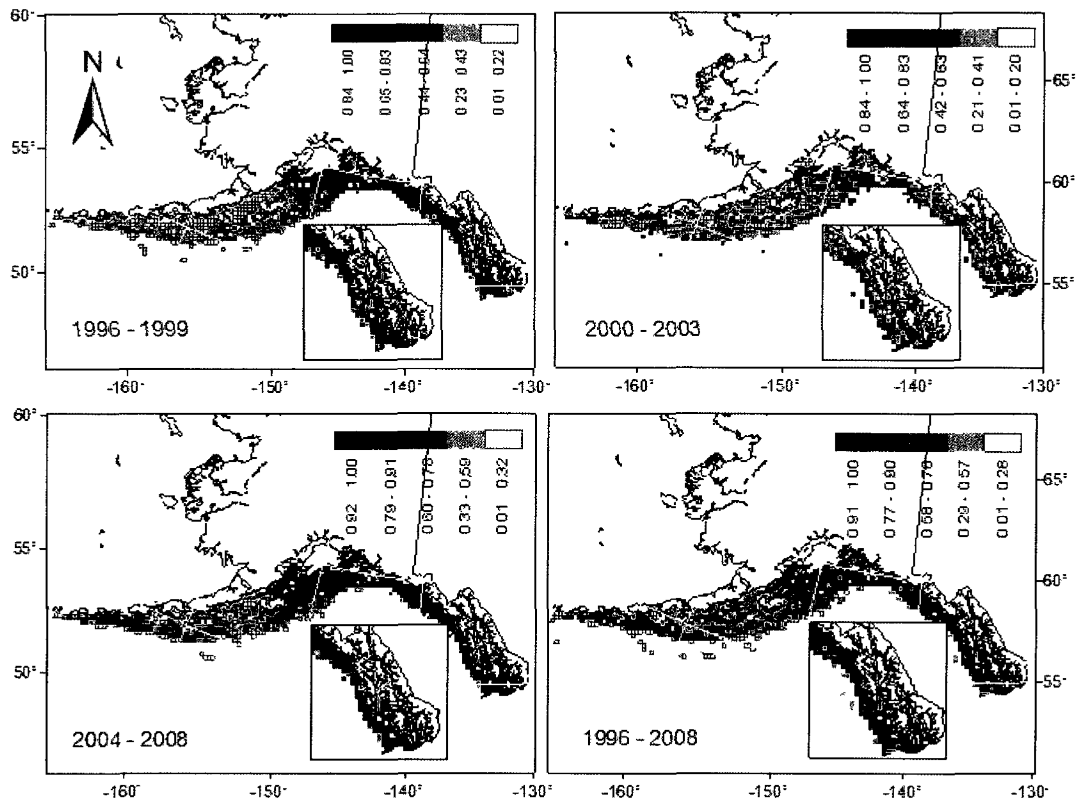


Figure 2.12. Mean predicated probabilities of the occurrence of dogfish in GOA based on the mean values from the binomial regression model. The trend from lighter to darker colors indicates a greater probability of the presence of dogfish in a 20 $km^2$ polygon.

# Chapter 3 Evaluation of the world market for spiny dogfish products and geography of supply[1]

## 3.1 Abstract

The spiny dogfish is a globally distributed shark species that is an important trade commodity for Europe and Asia. Dogfish have been over-exploited in areas that are important for market supply, primarily US, Canadian, and European fisheries in the northern Atlantic Ocean. Market impacts from the decline of dogfish are poorly understood, but recent media campaigns by environmental groups discouraging consumption of dogfish may reduce product demand. Data on trade, capture, and informal interviews with dogfish suppliers were used to characterize market channels and sources of demand in Asia and Europe. Market trends in Europe show drastic reductions in demand for dogfish, while market patterns in Asia are less clear. Structurally, the markets are segmented, with European markets segmented into frozen and fresh products and Asian markets comprised of frozen dogfish and fins. Future increases in market share for dogfish will require differentiating the product from potential substitutes while using eco-labeling and marketing to inform consumers.

[1] Gasper, J. R., J. Greenberg, G. H. Kruse, and Q. Fong. (In prep). Evaluation of the world market for spiny dogfish products and geography of supply. Prepared for submission to Marine Resource Economics.

## 3.2 Introduction

International seafood markets provide consumers with an abundance of year-round choices of seafood products. Firms compete for consumers who must decide among a myriad of seafood species and product types. In making these decisions, consumers compare price among seafood species and non-seafood sources, such as poultry or beef. Some consumers also consider whether the food source is healthy and sustainably managed (e.g., DEFRA 2011). This decision is often based on incomplete, inadequate, or errant information. This is particularly problematic in international markets. The origin of seafood is often ambiguous, leading consumers to rely on labeling, product attributes, or other information sources such as the popular media. For example, a fish species or mixture of species under a single market name may be harvested sustainably in one area of the world, but overfished in another. This composite of sustainable and non-sustainable supply sources adulterate dogfish markets. Markets with these characteristics are referred to as an adulterated market in this paper. Consumers concerned about sustainability may avoid purchasing fish from an adulterated market regardless of whether some channels in that market are sustainable. Ensuing declines in consumption cause reduced revenue and a smaller market share, both of which result in long-term economic harm throughout the market supply chain.

Eco-labeling is one solution to parse out environmentally sustainable products from non-sustainable products. A variety of seafood labeling and advisory programs are relied upon by consumers in making seafood purchasing choices. Some of the better known programs are the Marine Stewardship Council, Monterey Bay Aquarium Seafood

Watch Program, Friends of the Sea eco-label, Wild Alaska Seafood and Dolphin Safe Tuna. Formal evaluation of the market impact of these programs is limited due to economic data propriety, but the case of yellowfin tuna *(Thunnus albacares)* serves to illustrate gross effects.

In the 1950s an American purse seine fishery replaced a long-standing pole-and-line fishery for yellowfin tuna in the eastern tropical Pacific Ocean (Hall 1998; Enriquez-Andrade and Vaca-Rodriguez 2004). Although the purse seine fishery initially targeted free-swimming schools and those associated with floating objects, such as tree trunks, fishermen developed a technique that targeted tuna associated with schools of various species of dolphins. In the early years, dolphin mortality was high and the public became initially aware of this mortality in the 1960s. The US Congress responded to public concern when it passed the US Marine Mammal Protection Act (MMPA) of 1972. The MMPA required US fishermen to reduce dolphin mortality and banned foreign imports of tuna into the US from countries that did not have similar dolphin conservation programs. In 1977, member countries of the Inter-American Tropical Tuna Commission (IATTC) agreed to a dolphin conservation program and tuna from these countries was available for US consumption. However, poor documentation of dolphin mortality remained a concern and was addressed in the re-authorization of the MMPA in 1988. The reauthorized MMPA required observers on US vessels to document dolphin capture. Member states of IATTC also increased observer coverage during this period. Collectively, this legislation decreased annual dolphin deaths from very high levels (>100,000) to <5,000 per year (Teisl, Roe, and Hicks, 2002).

In the late 1980s, consumer concerns about dolphin mortality continued despite the reduction in catch and better catch accounting. Consumers responded by boycotting canned tuna products, which was the impetus to the US Congress to pass legislation in 1990 defining a "dolphin-safe" tuna label. This label is applied to tuna products where no dolphins were killed during capture; although vessels could still set gear around dolphins. Consumer response to the dolphin safe labeling program increased the market share for canned tuna (Tiesl, Roe, and Hicks 2002). However, some of these gains were likely lost in the 2000s when yellowfin tuna become publically controversial due to the bycatch of other species, such as turtles, sharks and other fishes, in gillnet, longline, and purse seine tuna fisheries. Additional concerns ensued from findings that some populations of yellowfin tuna were being overfished (Maunder and Watters 2001). In response, some retailers discontinued yellowfin tuna purchases (e.g., Best 2011) or only purchased sustainably labeled yellowfin tuna (FIS 2011).

A common thread through the history of the yellowfin tuna fishery is that public controversy highlighted negative amenities associated with the yellowfin tuna product. Moreover, conservation issues prompted legal action to change fishing behavior and encouraged suppliers to address environmental concerns by eco-labeling products. Suppliers were likely responding to reduced demand for yellowfin tuna or poor company image associated with selling yellowfin tuna products. Regardless, an economic pattern was followed such that controversy surrounding a product amenity reduced demand, prompted legal action, and suppliers mitigated economical loss by informing consumers (labeling) and changing business practices (e.g., only carrying sustainable seafood).

Spiny dogfish (*Squalus* sp.), also called "dogfish" or spurdog, provides a case study of a controversial and overfished species that is consumed in an adulterated market and may follow a similar economic path as yellowfin tuna.

This paper provides an overview of dogfish markets and market channels in the context of an adulterated market. A brief literature review about historical markets as well as biological and management issues is provided to understand the genesis of the modern market. We build on this review with an evaluation of the dogfish market in the 2000s using trade and capture statistics, and informal interviews with constituents that describe recent market trends and structure. Results are put into context with accommodating sustainability by differentiating sustainable products from their non-sustainable counterparts using eco-labeling as a marketing tool.

## 3.3 Biology and Management

Spiny dogfish is a common market name referring to elasmobranch species in the *Squalus* genus. Sharks in this genus are found in temperate coastal areas of the Pacific Ocean, Atlantic Ocean, Mediterranean Sea, and Black Sea (Compagno 1984). The common market trade name applies to several species: *S. acanthias* and *S. mitsukurii* that are widely distributed in the Pacific and Atlantic Oceans; *S. suckleyi* is found in the northern Pacific Ocean; *S. megalops* in the western Pacific Ocean, including waters off New Zealand and Australia; *S. montalbani* and *S. edmundsi* that range from the eastern Indian Ocean to the Pacific Ocean; *S. cubensis* and *S. mitsukurii* in the southern Atlantic Ocean and Pacific Ocean; *S. japonicas* and *S. brevirostris* in Pacific Ocean waters off Asia and the China Sea, *S. cubensis* found in the Atlantic Ocean off the coasts of South and Central America, the Gulf of Mexico, and off the coast of the southeastern United States (US); and *S. blainville* found in the eastern Atlantic Ocean, Mediterranean Sea, and Black Sea.

Spiny dogfish species within the genus *Squalus* are morphologically similar and are all vulnerable to unsustainable harvest. Spiny dogfish species are all characterized by slow growth, late maturity, longevity, and low fecundity; however, biological characteristics vary among species, which makes some species more susceptible to overfishing than others (Frisk, Miller, and Fogarty 2001; Cope 2006). For example, the biology of *S. acanthias* is dramatically different than the Pacific species *S. suckleyi*, which recently was re-classified from *S. acanthias* (Ebert et al. 2010). Morphologically the species are nearly identical, but *S. acanthias* grows more rapidly and matures earlier than *S. suckleyi* and thus, while both species are sensitive to recruitment overfishing, *S. acanthias* has a greater potential to recover from overfishing in a shorter time period (Ketchen, Bourne, and Butler 1983; Nammack, Musick, and Colvocoresses 1985; Fahy 1989; Henderson, Flannery, and Dunne 2002; Tribuzio 2010). Trade and capture statistics have not been revised to reflect this taxonomic distinction, but *S. acanthias* includes *S. suckleyi* trade. Describing detailed biology for all *Squalus* species in trade is beyond the scope of this paper, but the important point is that impacts from fisheries are different depending on the species (Johnston et al. 2005; ICES 2008). Spiny dogfish trade and capture statistics are often categorized as either unidentified or *S. acanthias*, despite range overlap (ICES 2008). This paper focuses on *S. acanthias* and *S. suckleyi*, but we note that species are likely misreported in trade and capture statistics and *S. suckleyi* is reported as *S. acanthias*.

Recent assessment information for spiny dogfish is available for a small number of species. Stock assessments have recently been conducted for *S. acanthias* stocks in the northeastern Atlantic Ocean waters (ICES 2006); stocks in the northwestern Atlantic Ocean (NEFSC 2006; MAFMC 2011); and *S. suckleyi* stocks in northeastern Pacific Ocean off British Columbia (Taylor 2008; Cindy Tribuzio pers. comm. 2010), and Washington, Oregon, and California (Taylor 2008). Dogfish stocks in the northeastern Atlantic are severely depressed (ICES 2006), while northwestern Atlantic stocks are rebuilding from formerly overfished status (MAFMC 2011). These assessments include biological modeling of populations and biomass estimates.

Fishery evaluations that rely on survey catch per unit of effort and fishery catch information have been conducted in several oceans. Recent evaluations were conducted for New Zealand (NZMF 2009) and Alaska (Tribuzio et al. 2010), both revealing stable abundance. However, based on fishery and survey information from the 1990s, the northwestern Pacific Ocean stock of *S. suckleyi* (JFA 2003) and the Mediterranean Sea stock of *S. acanthias* may meet Appendix II of the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES; FAO 2009b). We are unaware of recent assessments for other species.

During the 1990s, heavy fishing pressure in the northwestern Atlantic Ocean (US and Canadian exclusive economic zones) led to a small number of recruits between 1997 and 2003 due to excessive fishing on female dogfish (NEFSC 2006). Closure of the directed commercial fishery was implemented in 2000 to halt the depletion of mature female dogfish, which are favored in the market due to their larger size. Conservation measures (e.g., incidental catch limits and seasonal trip limits) promoted larger abundance and allowed an increase in commercial quota from 12 million lbs to 20 million lbs between 2009 and 2011 (MAFMC 2011).

In the northeastern Atlantic Ocean, the European Commission (EU) implemented commercial catch limits, based on historical catch levels, to rebuild dogfish stocks. However, rebuilding was hampered by excessive catch limits and poor catch accounting. By 2001, dogfish stocks in the northeast Atlantic were estimated to be as small as 5% of virgin biomass (Hammond and Ellis 2005; ICES 2006), prompting EU member states to close all directed fishing for dogfish in 2007. Further restrictions came in 2007 when the EU and Norway prohibited landing of spiny dogfish from their waters and in international waters of the northeastern Atlantic, except for vessels under 28 m using traditional gear within 4 nautical miles of shore. In other waters off Europe, dogfish catch is managed under a total allowable catch limit and a bycatch limit based on the percentage of landed weight of non-dogfish species.

### 3.4 Historical Market Overview: pre-1995

Historically dogfish fisheries have experienced boom and bust cycles caused by biological or market forces (Ketchen 1986; Gasper, Kruse, and Greenberg in prep.). Market share for spiny dogfish generally increases as product gains popularity or regulatory and biological conditions permit fishing opportunities, creating a boom. A bust occurs when the market disappears or mismanagement results in stock collapse. Even without markets, spiny dogfish are commonly caught incidentally in fisheries targeting other more economically desirable species.

Commercial utilization of spiny dogfish dates back to at least the 1870s when liver oil was used for lamps, machine lubricant, and as a source of vitamin A (Ketchen 1986). During WWII, demand for vitamin A increased, with dogfish liver providing an important source until the mid 1950s when a synthetic substitute became widely available (Ketchen 1986; Gasper, Kruse, and Greenberg in prep.). With the development of a synthetic supplement for vitamin A, demand for dogfish outside of Japan generally declined by the 1960s. In waters off Japan, dogfish harvest peaked in the early 1950s to accommodate a market for meat paste products, as well as demand for vitamin oil and fat (JFA 2003). Dogfish harvest remained strong through the 1970s until a severe decline began in the 1980s, which continues through the 2000s (JFA 2003).

A renaissance occurred in the European spiny dogfish market for meat during the late 1960s (ICES 2006; OSPAR 2010). The market was primarily supplied by northeast Atlantic fisheries, but as those stocks precipitously declined in the 1980s, supply from the US and Canada became more important. The US and Canada re-entered the market in the early 1970s and increased supply and marketing efforts to compete in Europe (Hanson 1971; Ketchen 1986). By the late 1990s, European spiny dogfish stocks collapsed and US and Canadian fleets relied heavily on revenue from spiny dogfish owing to declines of valuable target species such as Atlantic cod *(Gadus morhua)* and yellowtail flounder *(Limanda ferruginea*, Robinson 1994). Total landings of dogfish declined worldwide as those from the US and Canada did not offset reductions in European catches (FAO

2009a). In 1972, reported dogfish catch was approximately 73,000 t and declined to 16,600 t in 2007 (FAO 2009a). See Rose (1996) for a more expansive review of world dogfish markets prior to 1996. The reader is also directed to Ketchen (1986) for a more in-depth perspective on landings on the Pacific coast of Canada and the US prior to the early 1980s.

## 3.5 Market Overview: 1995-2009

Since 1995, world dogfish markets have been primarily meat products to Europe and both meat and fin products to Asia (Lack 2006). Figure 3.1 depicts the market channels for reported world trade of dogfish. In defining the market channels, the region of capture indicates the ocean region from which the dogfish was caught, the export region is the country exporting dogfish, and the market indicates countries consuming the dogfish. As shown in Figure 3.1, spiny dogfish originate from most oceans throughout their range, including the northwest and northeast Atlantic, northern and southern Pacific, including landings by countries from northern Africa, South America, New Zealand, North America, and northern Asia. During the 2000s, market share for dogfish products declined sharply during a period when northeastern (European waters) and northwestern Atlantic (Canadian and US waters) dogfish stocks declined from higher levels observed during the 1990s (ICES 2006). These stocks represented key supply points for the European market and their decline increased the reliance on dogfish imports from other parts of the world.

The severe decline of dogfish stocks in the northwestern and northeastern Atlantic and other waters surrounding Europe (e.g., North Sea) created concern by EU member states and environmental groups. Dogfish stocks are data poor with inadequate information about harvest and stock status in many areas of the world. These data concerns, coupled to known stock depletion issues in the northeast Atlantic Ocean, prompted the EU and environmental groups to petition CITES to regulate dogfish trade (CITES 2003; CITES 2007; CITES 2010). Although these petitions failed, they were successful at focusing media attention on dogfish products. Environmental groups capitalized on media attention and discouraged consumption of dogfish, particularly for fish and chips in the UK (e.g., Gray 2008; Watson 2009; Gray 2010). This type of attention encouraged consumers to seek substitutes, which likely lessened demand (Frank Merker, pers. comm. 2010). These trends affected demand for dogfish regardless of the products harvest source, as the country of origin for dogfish is impossible for consumers to distinguish.

### 3.5.1 Trade Data

We conducted an in-depth analysis of trade data to characterize market behavior during this recent period. Import and export data for the EU during 1995 to 2009 were obtained through the online portal Eurostat (http://epp.eurostat.ec.europa.eu, accessed April 2010). Eurostat contains records on product types, volume, and price in Euros of imports for EU countries and origin of import for both EU and non-EU countries. In addition, Eurostat contains information about re-exports and product types. The product types specific to spiny dogfish used in this study are broken into two market categories based on harmonized codes: Fresh or chilled dogfish of the species *Squalus acanthias* and frozen dogfish of the species *Squalus acanthias*. Harmonized categories that group dogfish with other shark species were not used for this analysis. Free on board (FOB) values for export trade data are reported through customs declarations by the reporting country. Cost, insurance, and freight (CIF) prices reported in Eurostat were used for import price data because FOB data were unavailable. Annual price data on imports were converted from Euros to US dollars using annual currency conversion tables available on Eurostat and adjusted for inflation using the Consumer Price Index (http://www.bls.gov/cpi, accessed April 2010).

Export information outside the EU was obtained from a variety of sources. Customs data on import, export, and value for fresh and frozen products were obtained from Statistics New Zealand (http://www.stats.govt.nz, accessed June 2010), and Statistics Canada (http://www.statcan.gc.ca, accessed June 2010). For New Zealand, export data are available on dogfish that are frozen whole, headed and gutted, and neither headed, gutted, or whole product for 2000-2008. New Zealand dollars were converted to US dollars using Reserve Bank of New Zealand exchange rate tables. Canadian data were available for fresh and chilled or frozen dogfish for 1995-2008. Data on the US trade of fresh and chilled and frozen dogfish products 1995-2008 were obtained from the US Department of Agriculture, Foreign Agriculture Division (http://www.fas.usda.gov/gats, accessed May 2010). Trade data from Japan, South Korea, and Hong Kong customs were examined, but trade codes were not specific to spiny dogfish and these sources were not used.

Data describing value demonstrated considerable variation within trade categories and among countries. Some of this variation is likely due to different product forms being reported under a single trade category of either fresh or frozen. For example, fresh prices may include whole dogfish skin on or off as well as backs. These product forms have varying levels of value adding that will influence reported price and the average prices could not account for a mixture of products within a category, which may vary considerably from shipment to shipment. There may also be variation in the quality of declared value and volume; however, this paper did not attempt to assess reporting accuracy, which is largely unknown.

Trade data were augmented with informal interviews of two dogfish processors in the US and one major fin importer in Hong Kong. Interviews were used as ancillary information to the trade statistics and to investigate market segmentation, product quality issues, market trends, substitute products, and processing constraints.

### 3.5.2 European Union Market

Spiny dogfish products consumed in the EU vary by region. Product forms include backs that are headed, gutted, and may be skinned; belly meat (flaps) from a headed and gutted dogfish; and whole dogfish that are either head on or off and gutted. Flaps are primarily consumed as smoked belly meat in Germany under the product name of *Schillerlocken.* Germany also has a small market for meat marinated in gelatin and sold as *Seeaal,* which means conger eel in English. Fresh or frozen backs and whole product has a wider range of consumption then flaps. These products are consumed in France under product names of *Saumonette* or *Chines*; in the UK as fish and chips under product names of flake, huss, rock salmon; in Italy with product names of *Spinaroli* and *Cazones*; and in minor volumes in Spain and other Mediterranean countries (Vannucci

1999). Fillets may also be sold in the market, but dogfish-specific information is unavailable.

Dogfish backs sold as fresh or frozen products have historically been an important fish product in the EU. The largest markets based on imports and domestic volumes have been France, the UK, and Italy, with smaller markets in Spain, Portugal, and Belgium. Imports into smaller markets may largely be re-exported to larger European markets with domestic consumption, but information on re-exports is not reliable. The Netherlands is believed to be primarily a supplier to other EU markets and has little if any domestic market for dogfish. Primary sources for dogfish into EU markets are the US and Canada, with direct import into all countries. France and the Netherlands both are likely major re-exporters of North American products to Italy (Figure 3.1). Market channels with low volume also exist between the EU and New Zealand, northern Africa, and South America, particularly for the Italian market. Consumption of shark meat is common in Italy (Welch et al. 2002) with fresh seafood products primarily distributed to domestic consumers by wholesale fish traders (FAO 2010).

### 3.5.3 Asian Market

Asian market channels for fin and meat products are difficult to distinguish due to poor reporting and grouping of dogfish into generic categories. Shark fins, including those from dogfish, are primarily consumed in China, although small amounts of dried product is re-exported to other areas (e.g., San Francisco). Trade statistics for fins are grouped into generic dried fin product categories and do not provide dogfish-specific trade information. However, dogfish fins that are not dried are exported as fresh or frozen product and are reported as such under harmonized codes. Export statistics reported by New Zealand, the EU, and US provide information about potential market channels (Figure 3.1). The export statistics indicate reported supply volumes and value, but they do not describe inter-Asian market channels or consumption patterns. Subsequent sections of this paper provide a starting point for future in-depth evaluations of Asian markets.

#### 3.5.4 Supply Sources and Value

Most imports into the EU originate from the US, with varying degrees on reliance depending on product type and country. Dogfish markets in France (Figure 3.2), UK (Figure 3.3), and Germany (Figure 3.4) all primarily rely on import from the US, Canada, and domestic sources (e.g., Norway, UK, France), although volume has decreased substantially since the late 1990s. These countries historically relied on inter-EU market channels to obtain dogfish, particularly fresh product from Ireland for the UK, which substantially declined in the late 2000s due to overfishing in the northeast Atlantic (Figure 3.4). Further, France relied on supply from on Belgium (likely includes some Norwegian imports) and the UK (Figure 3.4). Interestingly, Canadian imports have remained steady in the UK through the 2000s, but volume was less than 400 t. Italy has historically imported from the US and a diversity of other EU, Scandinavian, and non-EU countries, including Argentina, Mauritania, Netherlands, and inter-EU countries including Denmark, France, and Spain (Figure 3.5). Italy also relies on geographically proximate sources for fresh product, mainly France, the UK, and Denmark. Some of the inter-EU trade likely re-exports North American products, but data is lacking to distinguish volume for these inter-EU channels.

Export from the US for both fresh and frozen dogfish products peaked in 1996 before a precipitous decline to a stable volume of about 700 t by the mid 2000s (Figure 3.6). Between 1995 and 2009, frozen product was shipped to 35 countries across the globe; however, most countries had small volumes and few shipments. On average, 58% of frozen exports were destined for Germany (32% of the yearly average total, AA) and France (27% AA), with other important countries being the UK (10% AA), Belgium (9% AA), Thailand (5% AA), Malaysia (4% AA), Japan (4% AA), Australia (2% AA), and Hong Kong (2% AA). Exports to Japan declined during the period until they ceased in 2004, the cause of which is unknown (Table 3.1). During the same period, 28 countries received fresh product. France was the largest market for US exports of fresh product (47%), followed by Germany (11% AA), the Netherlands (11% AA), UK (10% AA), Belgium (5% AA), Italy (4% AA), Canada (4% AA), and Hong Kong (3% AA). Japan was also an important trade partner with the US for fresh product until 2005, with 5% of the annual average US export of fresh dogfish.

The primary port of exit for US products was Boston, Massachusetts, followed by New York, New York; St. Albans, Vermont; and Seattle, Washington (Figure 3.7). Product exported through St. Albans was likely destined for Canada where it was exported to other countries as there is no domestic Canadian market for dogfish. Dogfish was also historically exported from British Columbia to Washington State for processing (Ketchen 1986).

The price of US exports of both fresh and frozen products generally increased throughout the 2000s. Fresh product price increased from 4.13 USD/kg in 2000 to 5.42

USD/kg in 2006 before falling to 4.39 USD/kg by 2009. Exports to Italy in 2008 had the highest reported prices at 7.82 USD/kg, but fell to 5.19 USD/kg by 2009. Export price for the UK and France were within the same magnitude of the average price reported in the EU import statistics at 4.38 USD/kg and 3.59 USD/kg, respectively. Average frozen product value also increased from 2.88 USD/kg to 3.21 USD/kg during the same period. Frozen product exported to China was the most valuable, averaging 11.37 USD/kg, but volume was sporadic (Table 3.1). Thailand was a major Asian recipient of frozen exports, average 132 t annually with a range of prices averaging 4.58 USD/kg (Table 3.1). Frozen exports to France, the UK, and Germany ranged from 4.02 USD/kg (Germany) to 3.02 USD/kg (France) in 2009.

Canada is an important supplier of fresh products to the US, EU, and Asian countries. Exports from Canada peaked in 2001 for fresh product at 1,657 t and 2003 at 3,813 t for frozen product. The US and Canadian dogfish supply are linked, with 92% of the reported fresh export volume from Canada exported to the US for re-export (Figure 3.8). The remaining 8% of fresh product is exported to the UK (3% AA), the Netherlands (2% AA), Japan (1% AA), Asian countries, Germany, and France. Historically there were two important US export channels: dogfish caught in British Columbia were exported to Washington State and dogfish harvested in Nova Scotia were exported to US processors on the eastern seaboard. An important dogfish processor in Washington State closed in 2008, which will change future trade patterns.

Frozen dogfish products from Canada supply a much wider diversity of countries than fresh Canadian products (Figure 3.9). The main recipients are Japan (21% AA), France (21% AA), UK (13% AA), Germany (11% AA), Belgium (10% AA), South Korea (6% AA), Hong Kong (4% AA), Netherlands (4% AA), Italy (2% AA), and US (2% AA). Exports to Japan peaked in 1996 at 53% of total exports for that year and steadily declined to 2% by 2008. During that same period, export to the UK increased from 0% to 28% and export to Germany increased from 4% to 15%.

Whole dogfish that are not headed and gutted account for the largest portion (by weight) of New Zealand's reported dogfish exports. Recent (2000-2008) exports of whole frozen dogfish have averaged 890 t, ranging between 350 t (2004) and 1,278 t (2007). The majority of whole product exports are destined for South Korea, with sporadic exports to China and France (Table 3.2). Export price to South Korea is consistent between years and ranges from 0.42 USD/kg (2004) to 0.77 USD/kg (2006, Table 3.3). A small volume of export to France occurred in 2007 and 2008, with an average price of 2.29 USD/kg, consistent with import prices for France.

New Zealand also exports frozen headed-and-gutted dogfish products to Europe and Asia. This product was exported to 12 different countries between 1995 and 2008, with most destined for France and Germany (Table 3.4). South Korea also was a sporadic importer of dogfish during that period, with average price per kilogram generally similar to whole product prices (Table 3.5). Since 2005, prices for products destined to EU countries have been about 2.60 USD/kg, which is also consistent with those reported in Eurostat for frozen products. The annual deviation between EU countries importing frozen headed-and-gutted product is generally small, especially after 2005 when European countries have accounted for most of the export volume (Table 3.5). One exception is Germany in 2000 that had reported price of 10.71 USD/kg corresponding to 25.2 t of export. This price spike was not consistent with the Eurostat frozen import price information and may be a reporting error.

The highest priced New Zealand dogfish export is dogfish in the "other than whole-or-headed-and-gutted" category. This product was exported to 26 different countries between 1995 and 2008, and given the high variability in price between countries there is a likely strong consumer preference for specific product forms (Table 3.6). Large price variations occur between EU and Asian countries, with EU countries generally having a lower price (Table 3.7). The price discrepancy could indicate value added product forms in terms of particular meat cuts that consumer prefer for specific markets, such as differences in value adding for the Asian fin market (fin removed following standard method) and EU meat markets (e.g., skinned backs). The export prices from New Zealand were of similar magnitude as those reported in Eurostat for imports and likely reflect consumer preferences between Germany and other EU countries, with German import of belly meat being used for a smoked product.

Several Asian countries imported high-valued dogfish products from New Zealand. These high prices could indicate frozen product, including pectoral and caudal fins entering the shark fin trade. The New Zealand data indicate that Hong Kong and Thailand have the largest volume of high-value dogfish products, with Singapore and the Philippines accounting for small amounts (Table 3.8). Hong Kong, Malaysia, Philippines, and Singapore are all countries that import fins to meet Chinese market demand. Values for these countries since 2000 ranged from 6.00 USD/kg to 13.16 USD/kg and increased through the time (Table 3.9).

Based on export data, the dogfish market appears to be structurally different between European and Asian countries. These structural differences include the type of product consumed, the price paid for products, the supply chain, and volume. European consumption is solely focused on meat while the Asian market has demand for high value fins and lower value whole dogfish that is either domestically consumed or re-reprocessed into fins. Assessing whether price arbitrage is occurring for EU exports between the US, Canada, and New Zealand is difficult given local consumer preferences for certain products forms and the grouping of different product forms within a trade category. However, across all years it appears there is some price parity between dogfish export as evident by approximately comparable prices between New Zealand and the US in comparison to EU import. This is evident by the range of frozen export prices from New Zealand to France, the UK, and Italy being within the same magnitude of those reported in Eurostat. This result is not unexpected given both New Zealand and the US supply similar products forms, and minor volume of import to the EU from New Zealand. However, parity among Asian countries could not be evaluated since inter-Asian market channels for dogfish are unknown. For example, large export volumes to South Korea and lack of import to the EU suggest consumption in Asia, but the disposition of products and market structure is unknown. Interestingly, the whole frozen dogfish export from New Zealand to South Korea had the lowest price of any country, but the disposition of this dogfish is unknown, particularly whether it is being re-processed and re-exported to other Asian countries. Further, Russian markets for dogfish and domestic harvest are unknown, but in recent years (2007-2008) New Zealand reported large exports of frozen dogfish to Russia, which was not a major exporter to EU markets.

### 3.5.5 Health Issues: Mercury

Methyl mercury is a substance commonly found throughout the world and which originates from anthropogenic and natural sources. Mercury is not readily excreted by biological organisms and thus tends to accumulate over time (FDA 2009). Through the process of biomagnification, mercury concentrations increase with trophic level and age of fish, resulting in top level predators having the highest concentrations of mercury (Pethybridge et al. 2010).

The EU establishes regulations governing the allowable amount of mercury in fishery products. The EU commission regulations stipulate a maximum of 1 mg/kg of mercury may be present in imported dogfish product. The Border Inspection Post (BIP) of the first point of entry into the EU verifies documentation, physically examines the product, and checks the identity of the product lot as indicated on the Common Veterinary Entry Document (CVED). Part of the physical check may include testing the product for compliance with EU mercury regulations. The product may pass through the BIP and onto the EU consumer; however, if the product is later determined not to meet regulatory requirements, it may be placed on a Reinforced Control Status (RCS) and a Rapid Alert Notification sent to EU members. This alert indicates the product is out of compliance and the distributor of the product must take corrective action (e.g., destroy the product) for the product lot in question. The alert also triggers mandatory testing of products originating from the exporter. An exporter on RCS must have its ten next consecutive shipments to the EU (these could be small shipments, such as samples) systematically tested. During these tests, and until the results are known, products are detained at the BIP. After ten shipments without negative results, the exporter in question will be removed from the RCS list. The exporter may also choose to stop sending shipments to the EU for three consecutive months.

Penalties imposed by EU countries for failing mercury tests impose a cost on both parties involved in the shipping transaction. These costs include destroyed product, recall of product, transportation costs, testing costs, loss of revenue due to product being pulled from market, and potential long-term costs if consumers and purchases along the supply chain doubt product quality. As a result, suppliers must consider the size of dogfish caught and the location, with some locations having higher concentration of mercury. For example, older dogfish in Puget Sound have higher mercury concentrations (Hall, Teeny, and Gauglitz 1975). Mercury concentrations were lower in less industrialized areas of Puget Sounds, but the authors noted that samples sizes were small. Dogfish sampled in British Columbia (Forrester, Ketchen, and Wong 1972), Oregon (Childs, Gaffke , and Crawford 1973), and a study conducted by the Alaska Department of Environmental Conservation in 2009 shows a similar range of methyl mercury concentrations. Methyl mercury may be less of a problem in the northeast Atlantic (Greig. et al. 1976) compared to the northwest Pacific. Suppliers mitigate mercury contamination by mixing large and small dogfish, potentially from multiple locations, in shipments to reduce average mercury content in the lot. The annual costs associated with mercury problems in dogfish are unknown, but occasionally shipments fail to meet EU standards and are reported in the Rapid Alert System for Food and Feed (http://ec.europa.eu/food/food/rapidalert/index_en.htm.).

## 3.6 World Capture Data

To develop a synthesis of dogfish harvests throughout the world, data on landed catch (i.e., estimated round fish weight) were obtained from different sources depending on the country of landing. Landings for the US were obtained from the National Marine Fisheries Service (http://www.st.nmfs.noaa.gov/st1/commercial/index.html, accessed January 2010) and the Pacific Fisheries Information Network (PacFIN, http://pacfin.psmfc.org/pacfin_pub/contacts.php, accessed May 2011). Canadian landings by province were obtained from Statistics Canada (http://www.statcan.gc.ca/start-debut-eng.html). For countries outside Canada and the US, we obtained annual catch data compiled by the United Nation's Fisheries and Agricultural Organization (FAO 2009b). The FAO data underestimate catch in developing countries, when catch is not speciated, and for non-reporting countries (Graaf et al. 2011). Despite these issues, the FAO data remain a comprehensive source of information on world capture volume.

### 3.6.1 Regional Landings Overview

Landings were historically highest in the northeast and northwest Atlantic, with smaller but important landings from the southwest Pacific (e.g., New Zealand) (Figure 3.2). The supply of dogfish from the northwest and northeast Atlantic declined between 1995 and 2009 due to unsustainable fishing practices (ICES 2006; NEFSC 2006). Spiny dogfish harvest reported to the FAO (2010) for the northwestern Atlantic Ocean declined by 75% from 23,709 t to 5,833 t, after a low of 3,306 t in 2003. Reported landings in other ocean regions have not compensated for the decline in the northwestern Atlantic. For example, harvest in the northeastern Atlantic declined from 25,286 t to 2,916 t between 1995 and 2009. Other areas of import supply include the northeastern Pacific Ocean off Canada, Oregon (US), and Washington (US; mean harvest = 4,611 t; st. dev. = 1,564 t) and the southwestern Pacific Ocean (mean = 4,060 t; st. dev. =1,365 t), both of which remained steady during the period.

Spiny dogfish harvest is largely unknown in the southwestern (Africa) and southeastern Atlantic (Argentina and Brazil); southeastern Pacific (Chile); and western Pacific near Asian counties such as Japan and China. Japanese landing volumes are likely small, with 112 t caught from the northwest Pacific in 2001 (JFA 2003). FAO statistics are incomplete and do not contain landings of dogfish in waters off Japan despite evidence of harvest or Mauritania despite EU trade with that country. Japanese harvest in particular was large in 1952 at approximately 50,000 t, but experienced a drastic decline in the 1960s and is likely still low based a reported value of 112 t in 2001 (Taniuchi 1990; JFA 2003).

### 3.6.2 European Landings

The trade flow from domestic and foreign market channels into Europe has changed in response to decreased northeast Atlantic dogfish stocks (Figure 3.10). This decrease is most dramatic for UK vessels, with landings in 2007 representing only 8% of the total landings in 1995. Similar trends in landings occurred for France (38%), Ireland

(<1%), and other EU states combined (13%), which likely corresponds with increased regulations in the EU prohibiting landings due to overfishing of dogfish. Imports increased in relation to domestic landings for all major EU dogfish markets, but not at levels that offset losses in domestic supply. This trend is evident for UK-flagged vessels for which imports increased from 15% in 2003 to 51% of the total supply by 2007 (Figure 3.10). A similar trend is observed for France and Germany, where imports account for at least 75% of the dogfish supply (Figure 3.10). Italy is also reliant on imports, reporting no domestic landings between 1996 and 2007, during which the amount of imports declined approximately 50% (Figure 3.3).

### 3.6.3 US Landings

Between 1995 and 1997, over 90% of all dogfish exported from the US originated from the Atlantic Ocean. Landings increased in the 1990s until a peak in 1996 and 1998 with 95% of harvest from the Atlantic Ocean. In the 2000s, overfishing and regulatory restrictions led to a precipitous drop in landings. Overall landings continued to decrease from a high of 24,130 t in 1996 to 1,416 t in 2004. Landings have increased only slightly since 2004 to approximately 4,000 t in 2008, with the proportion of landings from the Atlantic Ocean shifting from 60-70% between 2003 and 2005 to > 80% between 2005 and 2008.

Regulatory controls on catch and differences in processing capacity between states influence the distribution of US Atlantic landings. Massachusetts accounted for most of the exported dogfish during the high production years of 1995 to 1998, when the state accounted for more than half of all landed dogfish in the US. After 1998, Massachusetts accounted for 34-52% of US landings, with the exception of 2000, when tighter regulatory controls resulted in reduced landings. In 2000, most of the dogfish landings were distributed among New Jersey (2,369 t), North Carolina (1,610 t), and New Hampshire (1,059 t). In recent years, approximately 1,300 t in 2007 and 1,600 t in 2008 was landed in Virginia and Massachusetts.

The majority of dogfish landings on the US Pacific coast occurs in Washington, with smaller amounts off Alaska, Oregon, and California. Landings in Washington peaked at 2,266 t in 1994 before declining to 552 t by 2008. The closure of a major processor in Bellingham in 2008 marked a major turning point for Washington's dogfish fishery (Frank Merker, pers. comm. 2010). The closure is likely responsible for a substantial decline in Washington's dogfish landings to just 99 t by 2010. Dogfish landings into Washington are likely to remain very low for the foreseeable future given 2011 legislation (SB 5688) that bans possession of dogfish fins and federal restrictions on catch amounts and areas open for fishing. Landings in Oregon and California remain low, ranging between 20 t in 2006 to 132 t in 2010. The major ports of landing in 2010 for Washington, Oregon, and California were West Port, Washington (84 mt), Astoria (57 t) and Newport (60 t), Oregon, and Monterey, California (5 t). In general, fisheries off Alaska land only incidentally caught dogfish that are processed into low-value meal product. Between 2007 and 2009 meal production of dogfish in Alaska ranged from 32 t to 35 t, with Kodiak being the primary landing port and small and sporadic amounts landed into Yakutat. Due to confidentiality restrictions, these small amounts cannot be reported.

The US Shark Conservation Act of 2010 prohibits the practice of cutting the fins off all shark species (except smooth dogfish) while at sea. Processing of dogfish instead occurs at shoreside processing plants where fins are retained in addition to backs and belly products. In addition to the previously mentioned Washington State legislation, recent Oregon legislation (House Bill 2838) bans the sale, trade, and possession of shark fins, but exempts spiny dogfish from this prohibition for licensed processors. This legislation acknowledges that dogfish can be sustainable managed and the practice of cutting the fins off the shark at sea prior to releasing the live animal is not occurring in the Oregon dogfish fishery.

### 3.6.4 Canadian Landings

Between 1995 and 2008, landings occurred on both the Atlantic and Pacific coasts of Canada, with approximately 60% from the Pacific (Figure 3.11). In general, Canadian dogfish landings increased for both coasts between 1995 and the early 2000s before declining to approximately half of peak levels by 2008 (Figure 3.11). All landings in the Pacific occurred in British Columbia and nearly all of the landings in the Atlantic between 2005 and 2009 occurred in Nova Scotia. Smaller landing amounts occurred in Ontario, New Brunswick, Prince Edward Island, and Newfoundland.

## 3.7 EU Market Analyses

The preceding qualitative analysis of supply and market channels informed the development of a quantitative model to investigate differences in price between important EU markets. Based on the qualitative analysis, we identified four major EU dogfish importing countries: France, Italy, Germany, and UK. It is hypothesized that markets with large price differentials reflect differences in consumer preferences for product forms. These preferences reflect local consumption patterns of dogfish and may respond uniquely to decreasing supply, which will increase price unless close substitutes are readily available. Identifying the statistical associations between countries, price, and supply is also one method to tease out market patterns among countries or even potential differences in import costs of insurance and freight.

We conducted statistical analyses of price trends among these counties and annual world harvest to investigate potential market segmentation and price response to supply. Results do not constitute supply and demand equilibrium or bioeconomic models nor are they intended to be used for predicting future price at a given quantity of dogfish. An equilibrium model was not attempted due to the sparseness of historical world dogfish supply data lack of biological models to estimate supply and harvester revenue and cost feedbacks. However, investigation of statistical differences between EU countries will show market specific price responses through time and at differing levels of dogfish supply, while considering the highly variable nature of the data.

The nature of potential statistical relationships between price and supply were unknown in advance, so several alternative models with differing error structures and covariates were evaluated. Fresh and frozen products were always modeled separately due to large annual differences in price and volume. For each product type, three models, each with a different fixed effect structure and a random year effect, were contrasted (Models 1-3) to a linear model with no random effect structure (Model 4). Random year effects allow temporal influences to be investigated when other statistical techniques lead to over-parameterized models (Zurr et al. 2009). However, investigating models without temporal effects is important to determine the most parsimonious model and whether time is an important variable. For this analysis, three fixed effect structures with an increasing number of covariates were examined for each product type:

$$P_i = \alpha + r_i + \varepsilon_{ij} \qquad \text{model 1}$$

$$P_i = \alpha + C_{ij} + r_i + \varepsilon_{ij} \qquad \text{model 2}$$

$$P_i = \alpha + C_{ij} + S_i + r_i + \varepsilon_{ij} \qquad \text{model 3}$$

$$P_i = \alpha + C_{ij} + S_i + S_i : C_{ij} + \varepsilon_i \qquad \text{model 4}$$

where: $\alpha$ is the intercept, $C_i$ is a dummy variable for country *j* reporting price *($P_i$)* in year *i*, and $S_i$ is FAO world harvest in year *i*. A Laird-Ware (1982) random effect structure *($r_i$)* described in Zurr et al (2009) was applied to models 1- 3 for each year *i*.

Models were fit using the R-Cran (R Core Development Team 2009) lme package (Pinheiro et al. 2009), which uses restricted maximum likelihood (REML) estimation. The Akaike Information Criterion (AIC; Akaike 1974) and the Bayesian Information Criterion (BIC; Schwarz 1978) along with residual plots were used to compare goodness of fit between models. Smaller AIC and BIC values indicate improved fits; however, the BIC is more conservative because it more heavily penalizes models with a larger number of parameters.

The EU cost, insurance, and freight (CIF) import price was used in model estimation. The CIF price data are not ideal in that they may include other costs not directly related to the market, such as transportation and freight insurance costs, but do not include tariffs or other taxes. However, the intent of the modeling exercise was to evaluate differences in price trends for markets. The CIF prices are useful because they reflect those differences, including the cost of getting product to market, which is likely passed on to consumers. Further, CIF prices can be discussed in context with FOB export prices from the US and New Zealand.

### 3.7.1 Price and Quantity Model

Convergence of the mixed effects and linear models was achieved for both fresh and frozen product types. Model 4 performed the best for the fresh product, whereas model 3 performed best for the frozen product as indicated by both the AIC and BIC goodness-of-fit statistics (Table 3.8), summary plots (Figure 3.12), and the quantile plot (Q-Q; Figure 3.13). Both the AIC and BIC statistics showed large improvements in fit when capture volume was added to the model (Table 3.7). Evaluation of fit over time showed good agreement with the time series. The Q-Q plots showed the theoretical error distribution was approximately linear with the observed values, suggesting the modeled error distribution is normal and a relatively good fit. However, one place where the model performance could not be corrected was for the frozen UK price, where the model consistently underestimated the UK price between 1995 and 1999, and overestimated the UK price for 2002-2004.

The random year effect had a large influence on fit in the frozen model, but not the fresh model. The standard deviation for the random year effect ($SD_r$) in the frozen model accounted for 46% of the random variation, whereas the year effect was not important for the fresh model (Table 3.8). This indicates that the fixed effects structure for the frozen model was unable to capture temporal changes in price response. The random year intercept was dropped for the fresh product model in favor a fixed effect linear Gaussian model (model 4).

Frozen product was fitted similarly by the mixed effect (model 3) and fixed effect models (model 4) as indicated by the AIC and BIC statistics. However, the models diverged at around 25,000 t of landings; the linear model indicated a flat slope between price and quantity while the mixed effects model indicated a steeper slope beyond 25,000 t (Figure 3.14). The fixed effect coefficients for model 3 were significant at the 95% level for the intercept ($t=3.16$, $p<0.01$, Table 3.9) and landing amount ($t=-2.91$, $p=0.014$, Table 3.9). Landings had a significant negative relationship with price, indicating a lower price per kg at higher quantities. There were no statistically significant country effects; nonetheless, on average the predicted value for frozen products for the UK was higher than for other countries and Italian prices were modeled to increase to a lesser extent with smaller volumes (Figure 3.14).

The fresh product model (4) showed a significant decreasing trend in price as quantity increased ($t=4.72$, $p<0.01$; Table 3.7). Coefficients for the countries and interactions between countries and volume were non-significant, except for Germany (Table 3.8). German price was trendless over time and did not respond to changes in supply (Figure 3.15). The significant interaction effects between supply and price made interpretation of country-specific effects difficult.

Generally speaking, the model predicted Italian prices to be much higher than other countries throughout the whole time series (Figure 3.15). The Italian prices never overlapped those of the other countries, suggesting consumer preferences for specific products. However, export prices in both the US and New Zealand show the Italian FOB price per kg to be consistent with France and the UK. Arbitrage between the EU markets may result in similar export prices, but other costs involved with shipping may inflate Italian import price; however, these costs are not known nor is it known whether Italian insurance and freight costs are higher than other EU countries. Retail price information for Italy was not available, but presumably the high import costs are being passed to consumers, resulting in higher market prices for dogfish in Italy. There is also a possibility of miss-reporting of information, but this could not be confirmed.

## 3.8 Discussion

Dogfish from throughout the world's oceans are entering into both the European and Asian markets. Based on the available capture and export information, Asian countries are dependent on frozen spiny dogfish products from New Zealand, with some minor amounts coming from the US and Canada. European markets are largely dependent on supply from the US and Canada. Since 1995, European markets have undergone large structural changes due to overfishing that are not as apparent in the Asian markets. However, one change observed in Asia was the emergence of Russia as an important dogfish import destination and the decline of Japanese imports in the mid 2000s. The reason for the decline in Japanese imports is not clear nor is the disposition of Russian dogfish.

Overfishing in the Atlantic Ocean has changed market channels in the major European dogfish-consuming countries. To offset diminished domestic harvest, European countries have relied heavily on imports from the east coasts of Canada and the US. The volume of these imports declined during most of the period examined and markets in Europe did not offset declines in supply by increasing import volumes from other regions, such as New Zealand, Alaska, or South America. Decreased supply is expected to increase price if demand for spiny dogfish products remained strong within each market segment. Higher prices create incentives to increase dogfish supply; however, our results show that this did not occur and demand for dogfish severely declined between 2000 and 2007. Evidence of reduced demand occurred in both fresh and frozen market segments.

An important weakness in our analysis is that we did not consider price trends for other whitefish species, such as Pacific cod (*Gadus macrocephalus*) and Atlantic cod. These species may substitute for dogfish in popular fried fish dishes, such as fish and chips, and likely influence dogfish price. During the late 2000s, dogfish prices increased as did US wholesale price for cod exports to the EU (Hiatt et al. 2009). The price increase observed for frozen dogfish products mainly occurred during the late 2000s and thus may have reflected both scarcity in dogfish supply and overall increases in marine whitefish market price. Regardless, total volume of dogfish in the EU market severely declined during the 2000s, indicating reduced consumption and, because price did not substantially increase in any segments, product demand also declined.

There are several possible reasons for the decline in EU dogfish demand. In most markets, substitution of with other marine whitefish is likely, given that dogfish consumption is a fraction of historical levels and that EU per capita seafood consumption is strong (Welch et al. 2002; DEFRA 2011). Moreover, whitefish species are easily obtainable, historically popular and relatively cheap compared with other fish species (such as salmon), and most species can be made into fish and chips or packaged as easily prepared frozen or fresh products. Whitefish products may be substituted for dogfish except in the specialized German market. However, product demand in Germany has decreased since 2000 and remains low due to public controversy towards dogfish (Frank Merker pers. comm. 2010; Matthias Kloppmann, pers. comm., 2011). Environmental campaigns during the early and middle 2000s were particularly strong in the UK and Germany, with the German government supporting regulation of dogfish trade (CITES 2003; Matthias Kloppmann, pers. comm., 2011). Other issues that influence supply are tighter regulatory restrictions on dogfish harvest in the US and Europe, and the cost of establishing new market channels in other parts of the world. Establishing new market channels is less attractive when consumers have a negative attitude towards dogfish and replacement products are easily obtained.

While this paper provides some insight into Asian markets, information on import volume is incomplete due to a lack of specific reporting for spiny dogfish in Asia. In particular, trade information on shark fins by species is very poor and the FOB prices presented are an annual average for a frozen product that may contain fins as well as other meat products. Despite these caveats, prices associated with certain Asian countries, such as Hong Kong (a known fin importer), are magnitudes higher then EU prices. Interviews with North American processors indicate raw unprocessed fins from the US are shipped to Hong Kong, Singapore, and Malaysia. This information coupled with fin prices on par with other studies (Clarke 2004) and market description provided by a Hong Kong fish buyer (Edwin Fong pers. comm. 2009), suggest New Zealand, Canada, and the US are important suppliers of dogfish fins to Asia, likely to meet Chinese market demand. In 2011, the US State of Washington prohibited the possession and sale of fins and similar legislation is being considered in California. Washington State represents a minor source of supply, but if other regions such as British Columbia or the Atlantic US follow this trend, structural changes to the dogfish fin market may occur. However, New Zealand is currently the most important supplier for dogfish to Asia and has the capacity to increase production to offset reductions in North American supply. Between 2006 and 2010, New Zealand used between 6,000 t and 8,300 t of spiny dogfish, which is lower than the 12,660 t catch limit (New Zealand Ministry of Fisheries, http://fs.fish.govt.nz/Page.aspx?pk=7&tk=100&sc=SPD).

China is the predominant market for sharks, with 50% of the shark fin bound for mainland China passing through Hong Kong (Clark 2004). The trade of shark fins through Hong Kong has grown substantially between 1995 and 2002, prior to a small decline between 2003 and 2005 (Clarke 2004; Clarke, Millner-Gulland, and Bjorndal 2007). The reasons for the decline are not clear and may be due to economic issues, such as the Asian Financial crisis, changes in consumer attitudes towards shark fin products, changes in import patterns of fin products into China, and underground trade (Clarke, Millner-Gulland, and Bjorndal 2007). In general, dogfish fins are of low value due to the small size of their fins with thin and short spindles. Despite the low quality associated with dogfish fins, prices for high-value dogfish (>$7 kg) shipments increased between 2005 and 2008. One possibility is that tighter regulations and stock declines for desirable fin species, such as hammerhead (*Sphyna spp.*) and tiger sharks (*Galeocerdo cuvier*), may have reduced imports and encouraged exploitation of lesser value species.

In response to the FAO's (1999) International Plan of Action for Sharks and political pressures (including changes to the MSA), the 2000s correspond to a period when restrictions on harvest methods were implemented by a few countries may have made dogfish fins more desirable. In some situations, fisheries were closed to finning (e.g., Hawaii longline) and other legislation attempted to prohibit the practice of removing shark fins at sea and releasing the finned shark back into the ocean while live. In other situations, species valued for their fins have declined due to overfishing (e.g., scalloped hammerhead, *Sphyrna lewini*) and their scarcity increases the price for shark fins. Thus, demand for fin products remains high while supply for valuable species may be lower, resulting in dogfish being used as a substitute for fins from more preferred shark species. Chinese demographics have also changed in the 2000s such that a larger portion of Chinese citizens have disposable income. Despite these market pressures, dogfish volume remained relatively stable for Asia, which may reflect catch limits in Canada, US, EU, and New Zealand, and a lack of dogfish off Japan. However, export price of frozen dogfish from New Zealand to Hong Kong, Singapore, and Malaysia increased, which may reflect changing shipment composition (e.g., meat versus fins) or indicate increased demand for fins. Other factors might also include unreported supply and inconsistent reporting of fins as "frozen dogfish product."

## 3.9 Conclusions

We provided a gross overview of the dogfish market supply chain and types of segmentation. The ability to evaluate markets is limited due to the scope of international capture data and likely the quality of reporting in some situations. Despite these issues, a clear pattern of segmentation was observed between the EU and Asia, and within the EU between Germany and Italy and France and the UK for fresh or frozen products.

A key finding in this paper is that consumption has declined in the EU across all segments. The reasons behind this decline are related to legal actions to rebuild dogfish stocks in the northeast and northwest Atlantic and consumer concern about sustainability and mercury health concerns. Hopefully conservation measures will improve overall stock health in the Atlantic, but repairing the market will require investment from suppliers. As with the yellowfin tuna example discussed in the introduction, one method to unadulterate the market, increase consumer confidence, and differentiate dogfish from replacement products, is to complement legal action (e.g., catch limits) with eco-labeling and education. As part of the product differentiation strategy, an eco-label may address consumer concerns about both mercury contamination and sustainably. For example, large female dogfish generally have the highest landing value; however, in comparison with smaller dogfish, they are prone to high mercury content and overharvest can lead to recruitment failures because they have higher reproductive success (NEFSC 2006). Markets focused on smaller individuals may address some sustainability issues and health concerns. Regardless, any labeling scheme should provide careful examination of fishery impacts on release mortality, fishery recruitment, demographics, and population structure among other factors. An interview-based survey of consumer attitudes and welfare would validate this finding and inform suppliers about segment-specific labeling strategies.

Information on dogfish consumption in Asian markets is incomplete due to a lack of data about inter- Asian and extra-Asian market channels and supply. Regardless, dogfish is clearly an important trade commodity in Asia and increasing world restrictions on fining practices may incentivize harvest of dogfish as other shark species become scarce. Since dogfish destined for Asian markets are coming from the same stocks as those for the EU, eco-labeling may provide economic incentives for stock sustainability and allow consumers in both markets to differentiate sources. Efforts are currently underway to inform Chinese consumers about the shark fin trade. Providing certified sustainable fin products would provide consumers choices and may encourage sustainable consumption.

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## 3.12 Figures

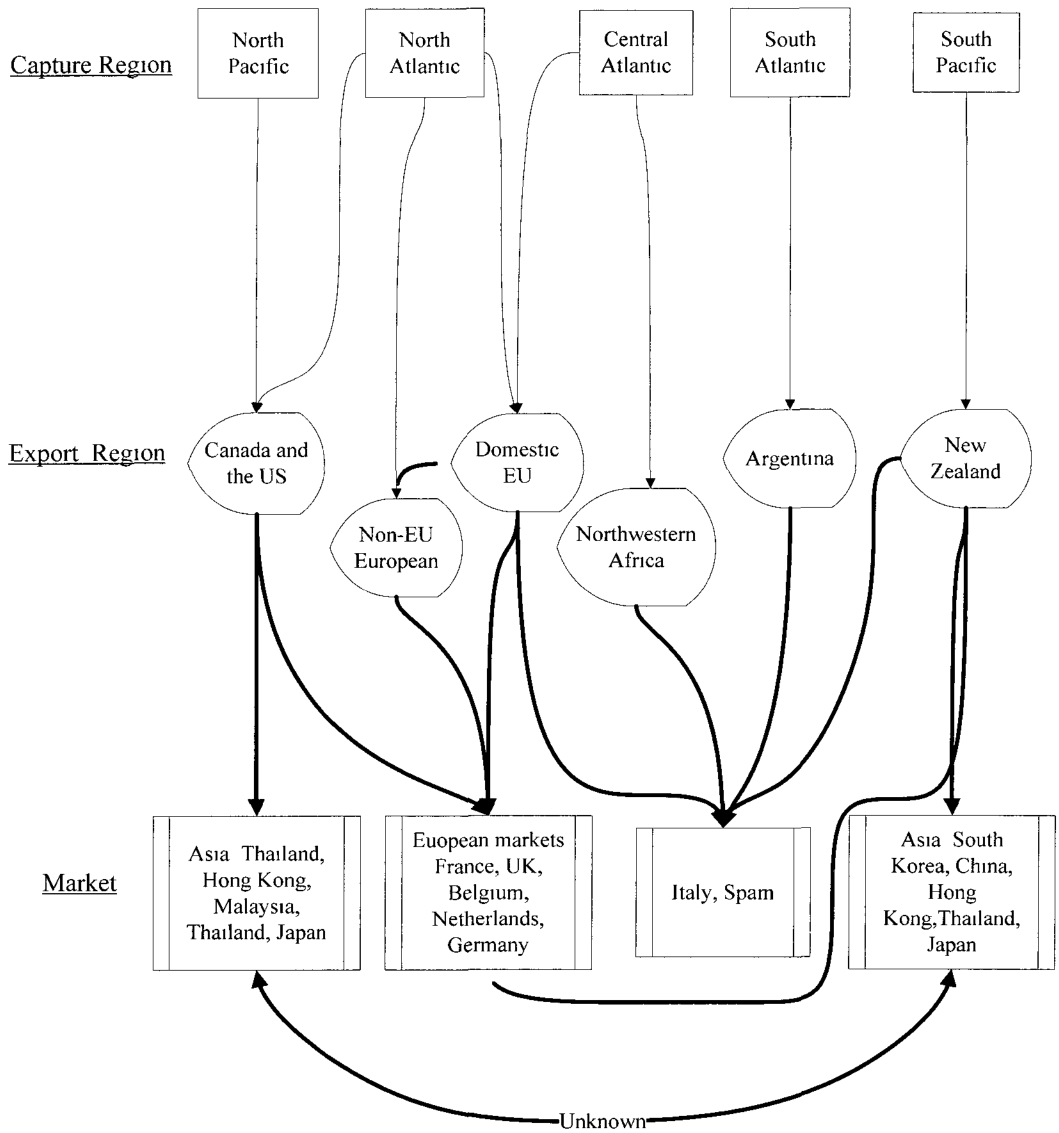



Figure 3.1 Overview of known major fresh and frozen market channels for spiny dogfish.

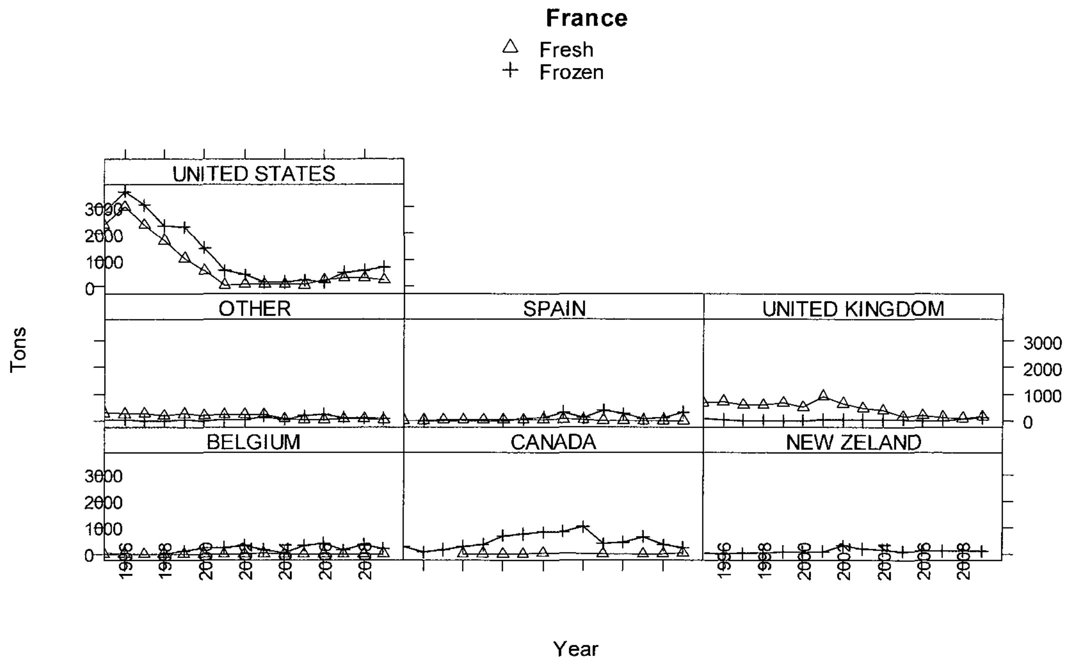



Figure 3.2 Summary of dogfish import volume into France by year, product type, and country of origin. Other countries include sporadic imports from Germany, Iceland, Netherlands, Turkey, Chile, Thailand, Brazil, Denmark, Guinea, Italy, Portugal, China, Greece, Sri Lanka, Sweden, South Africa, Mauritania, Congo, Faroe Island, Morocco, Senegal, and Argentina.

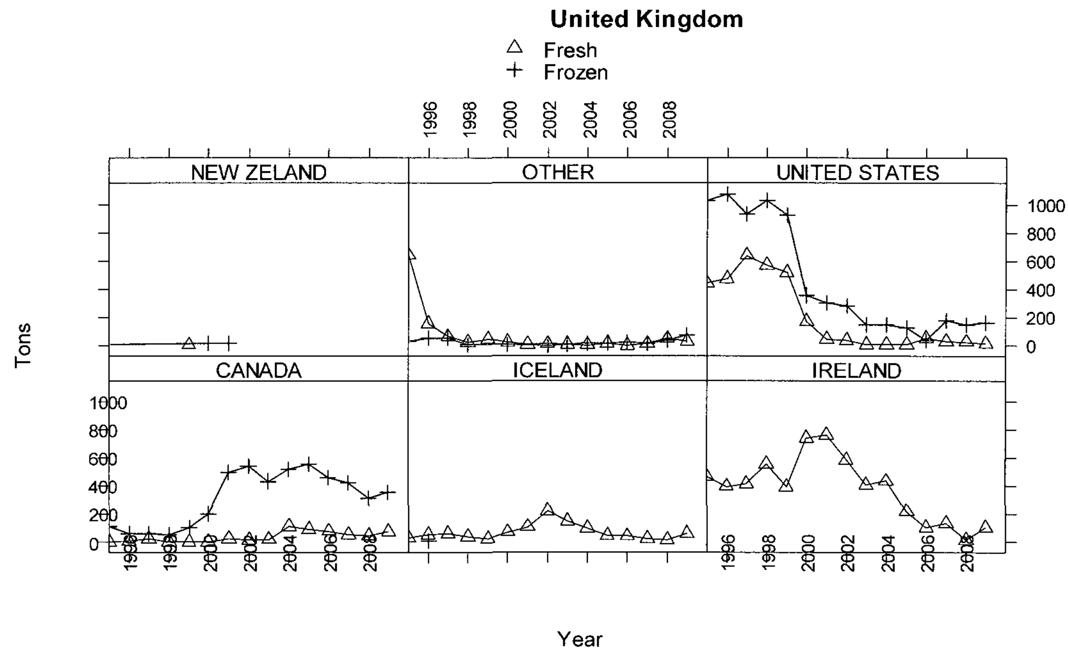



Figure 3.3 Summary of dogfish import volume into the United Kingdom by year, product type, and country of origin. Other countries include sporadic imports from Barbados, South Africa, Belgium, Denmark, Greece, Morocco, Omen, Chile, Brazil, Spain, Netherlands, South Korea, Faroe Islands, Norway, Yemen, and Norway. Eurostat import data used to generate graph.

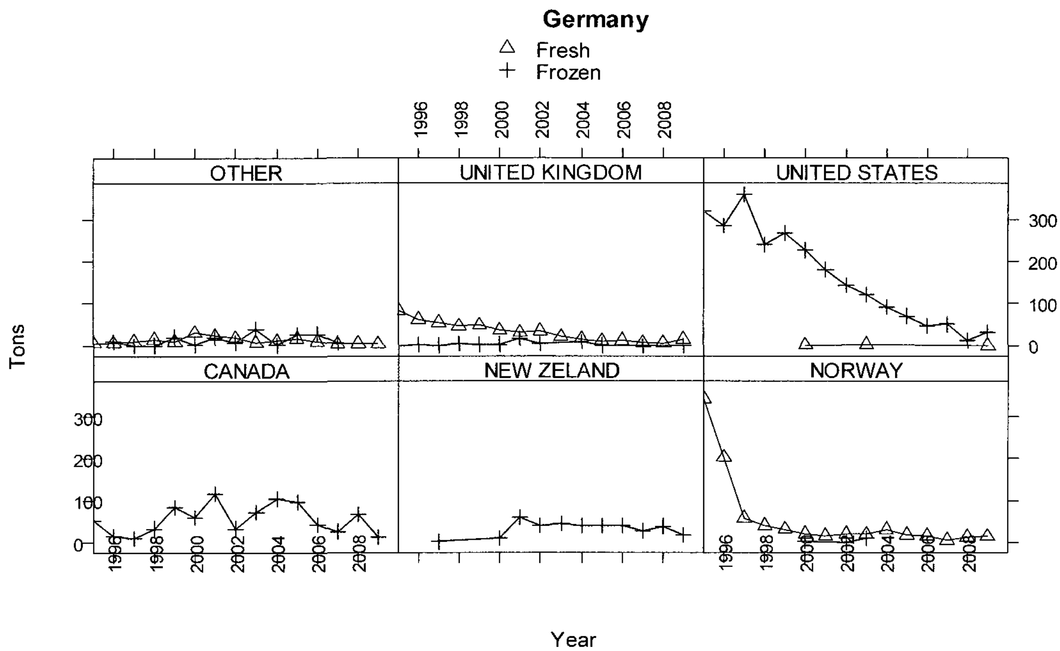



Figure 3.4 Summary of dogfish import volume into Germany by year, product type, and country of origin. Other countries include sporadic imports from Iceland, Oman, Chile, Taiwan, Denmark, Denmark, Sweden, Mauritania, Ecuador, Greece, Spain, Ireland, and Poland. Eurostat import data used to generate graph.

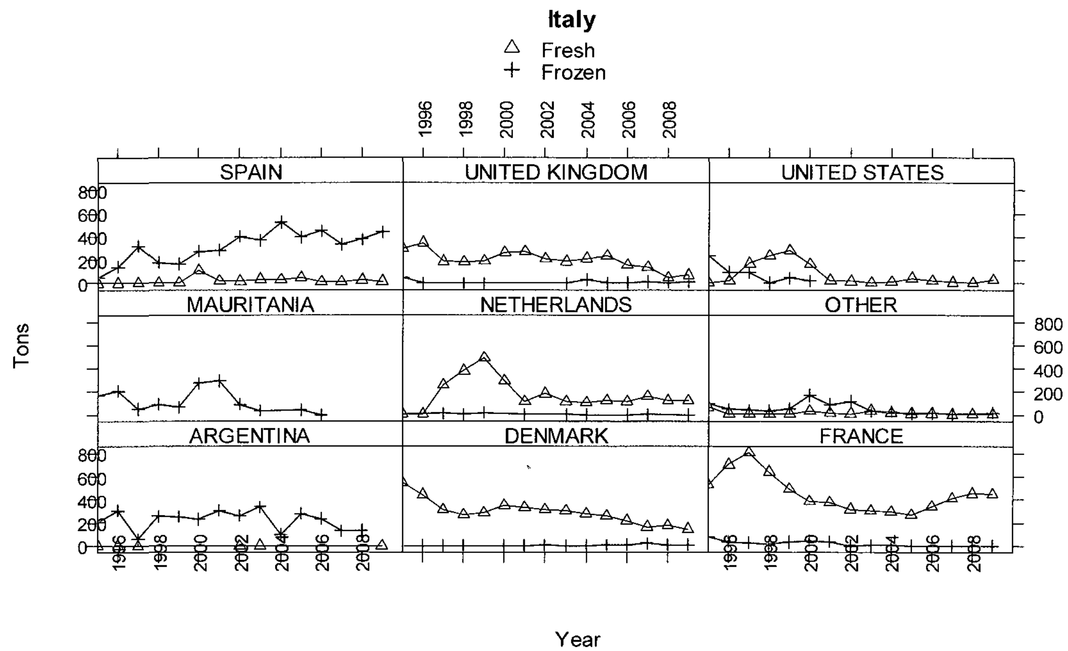



Figure 3.5 Summary of dogfish import volume into Italy by year, product type, and country of origin. Other countries include sporadic imports from China, Malta, Brazil, Slovenia, Angola, Cyprus, Ghana, Guinea, Greece, Honduras, Kenya, South Korea, Morocco, Oman, Singapore, Senegal, Thailand, Turkey, Uruguay, Yemen, and South Africa. Eurostat import data used to generate graph.

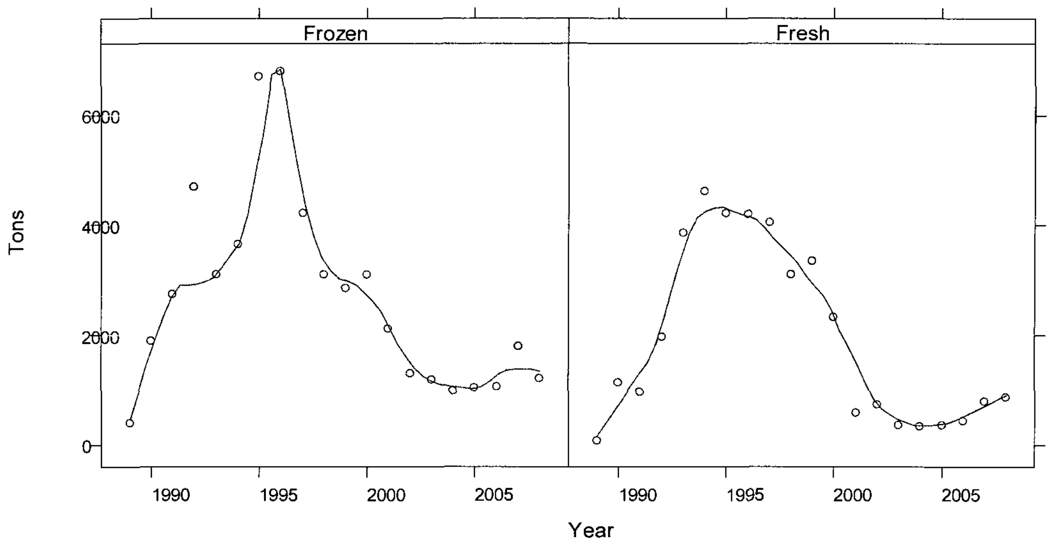



Figure 3.6 Volume of dogfish export by product type for the US between 1990 and 2007. A LOESS smooth with a span of 0.2 is used to show general trends. US Customs data used to generate graph.

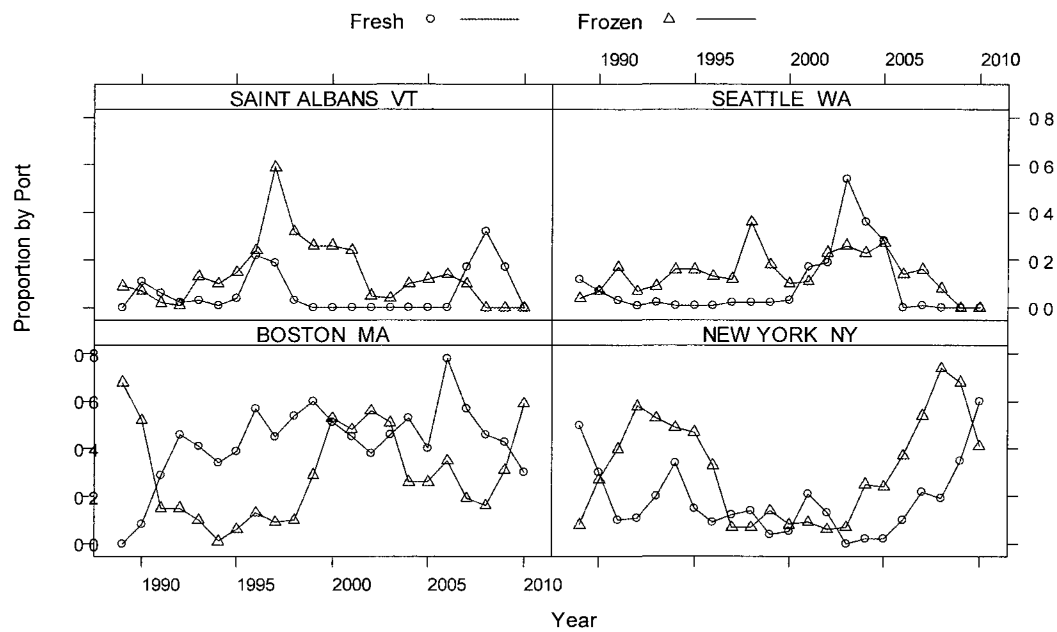
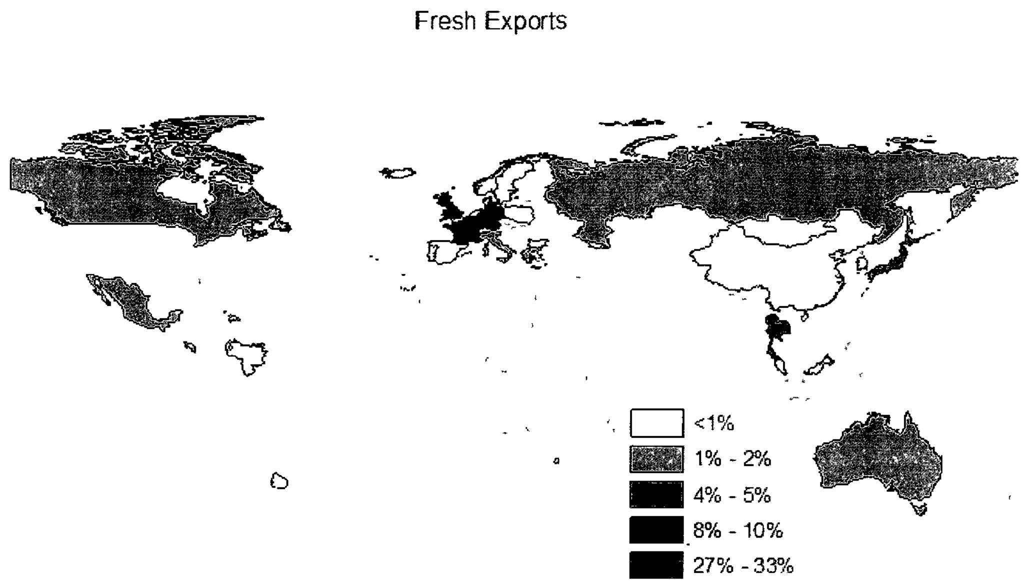



Figure 3.7 Proportion of dogfish export by port of exit and product type (fresh or frozen product). Proportions indicate the proportion of total export across all ports within a product type and year. US Customs data used to generate graph.



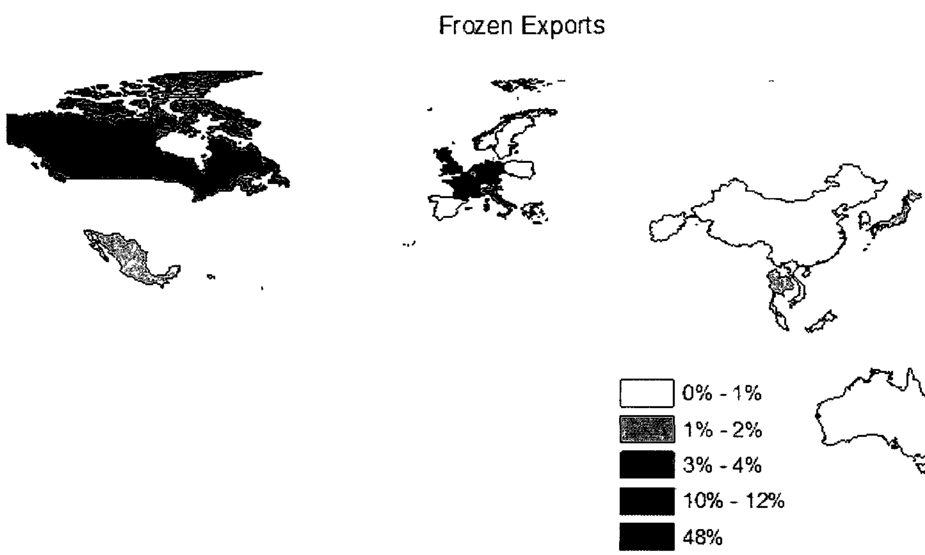




Figure 3.8 Average annual percentage of US dogfish export volume over 1995-2008. US Customs data used to generate graph.

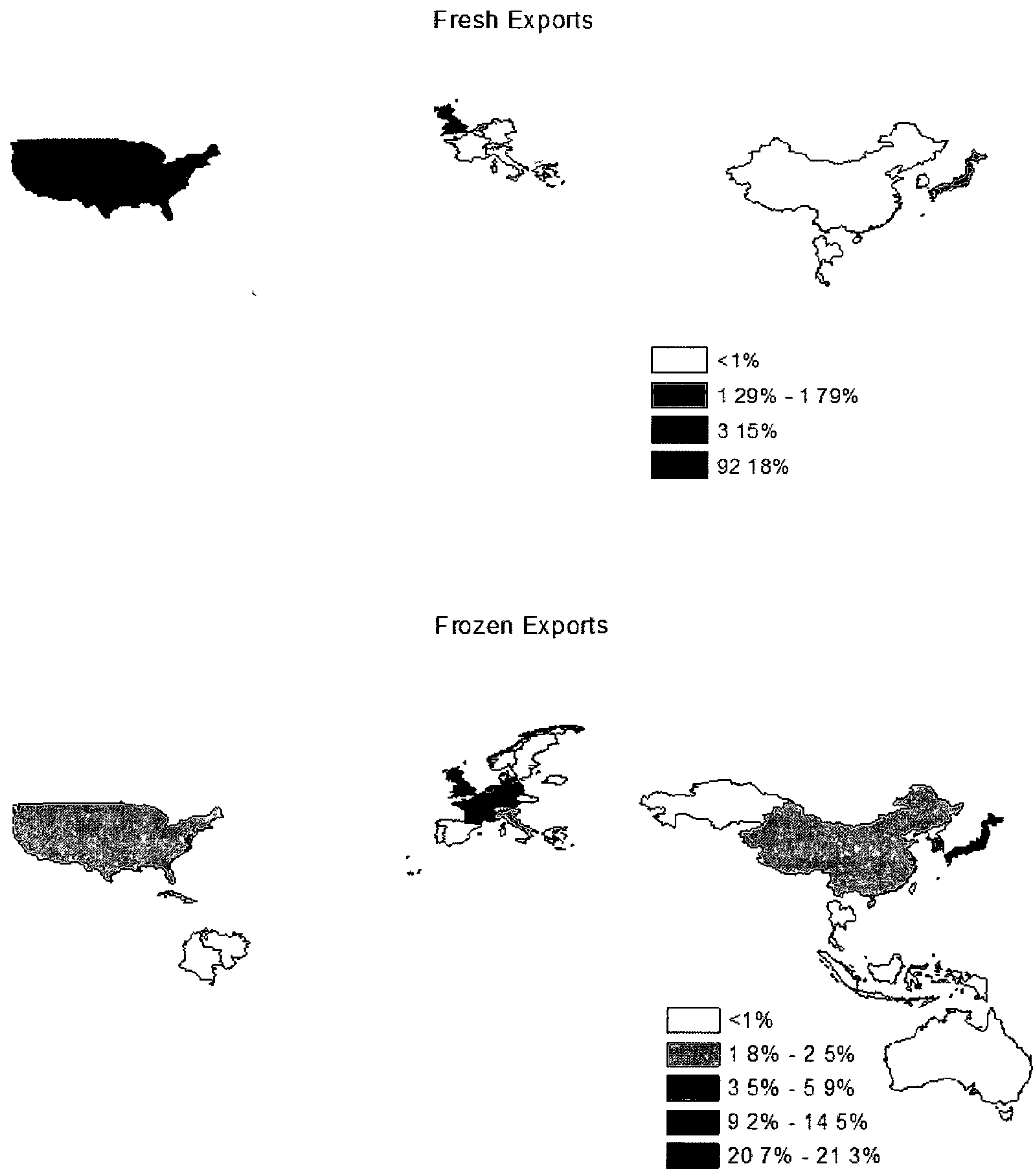



Figure 3.9 Average annual percentage of Canadian dogfish export volume over 1995-2008. Data use to generate map from Statistics Canada.

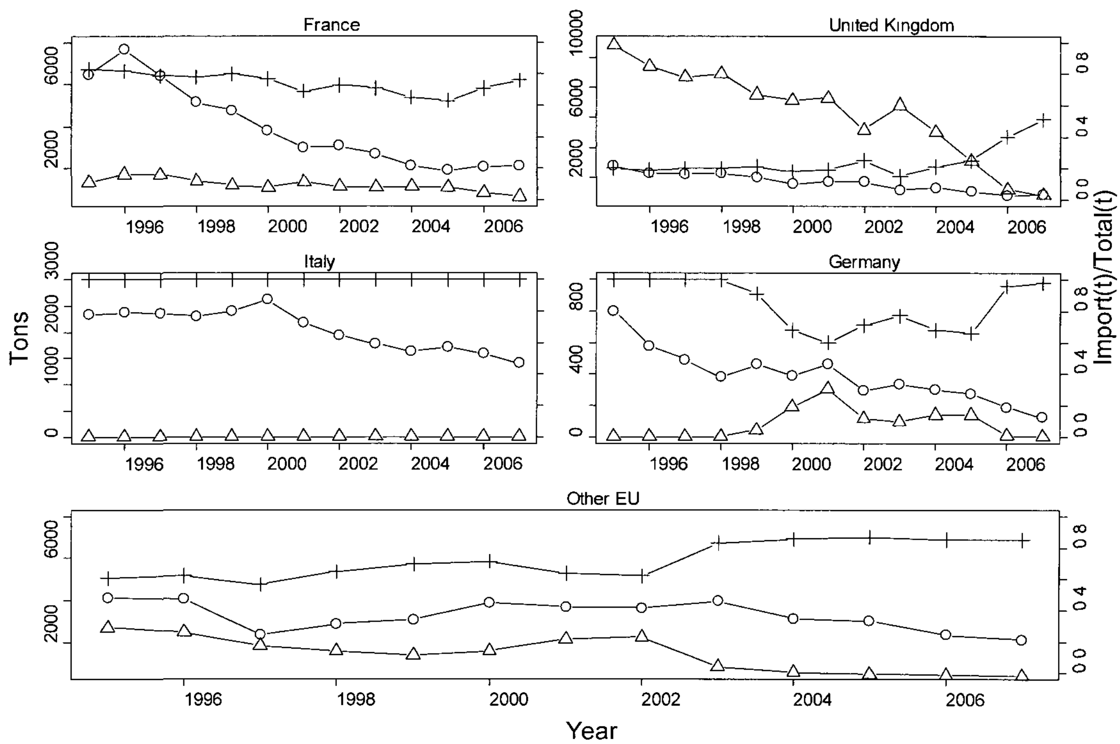



Figure 3.10 Total domestic dogfish harvest (t), import amount (t), and proportion of import to domestic harvest for France, Italy, United Kingdom, Germany, and all other EU countries. The left Y axis corresponds with the total domestic (Δ) and import data points (o). The right Y axis corresponds to the ratio of imports to domestic harvest (+).

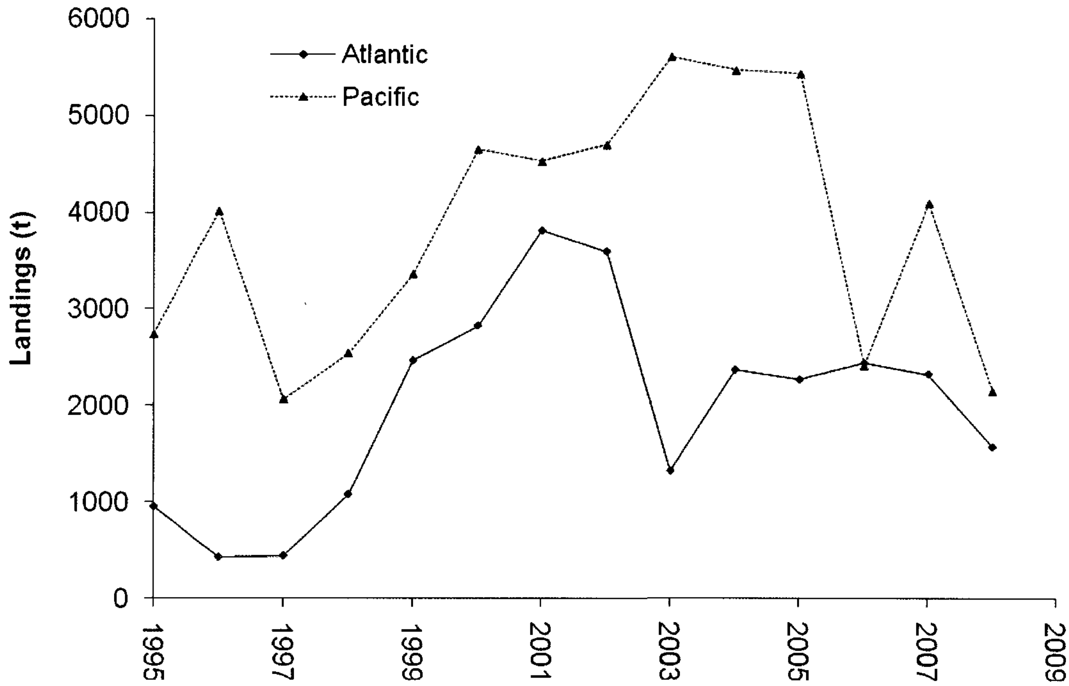



Figure 3.11 Reported Canadian landings of spiny dogfish for the Atlantic and Pacific Oceans between 1995 and 2009. Statistics Canada data used to generate graph.

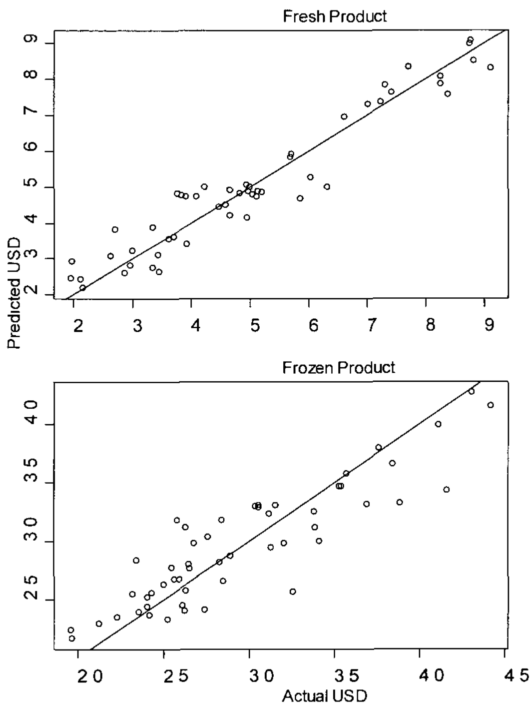
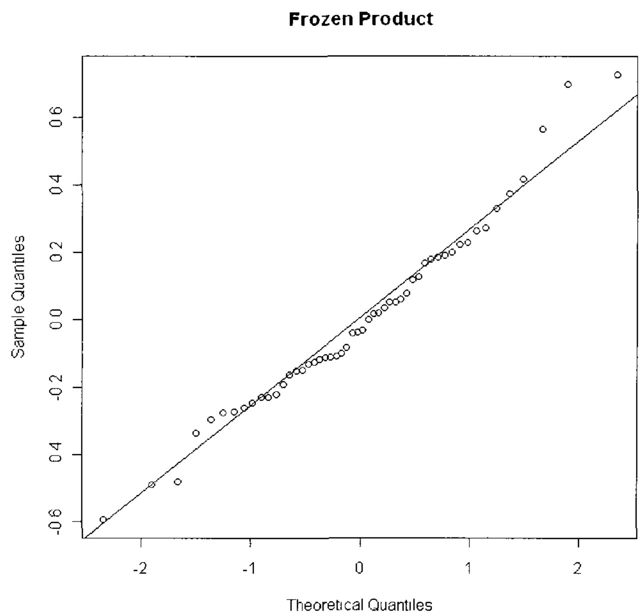



Figure 3.12 Model 3 fit for frozen product and model 4 fit for fresh product for spiny dogfish. The left panel shows predicted vs actual price (USD/kg) and the right panel shows model fit by year and country. Eurostat import data used to generate graph.



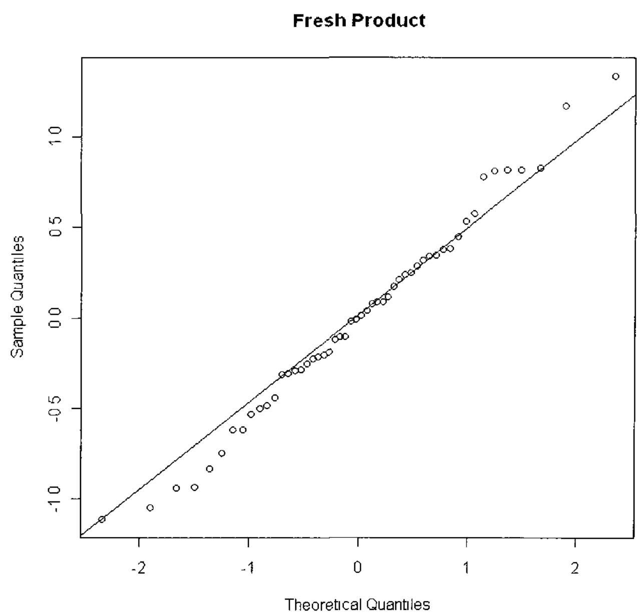




Figure 3.13 Quantile-quantile (Q-Q) plots of the residuals for model 3 (frozen product) and model 4 (fresh product).

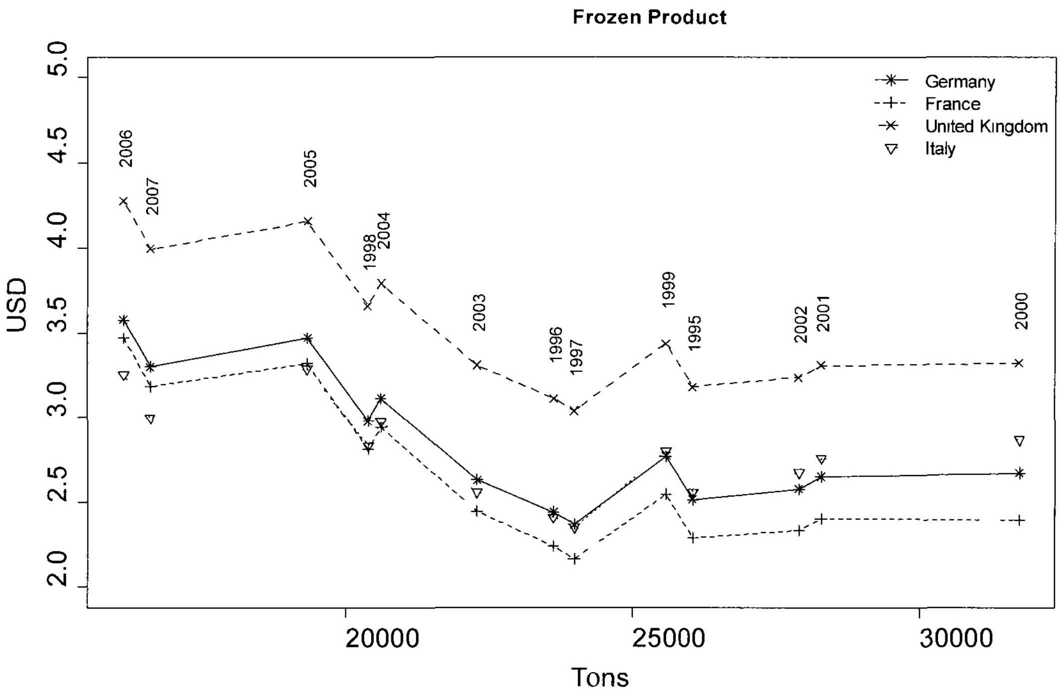



Figure 3.14 Model 3 predicted price (USD/kg) and quantity of frozen product of spiny dogfish for France, Germany, the UK, and Italy. Labels on UK values are the corresponding year for each data across all countries.

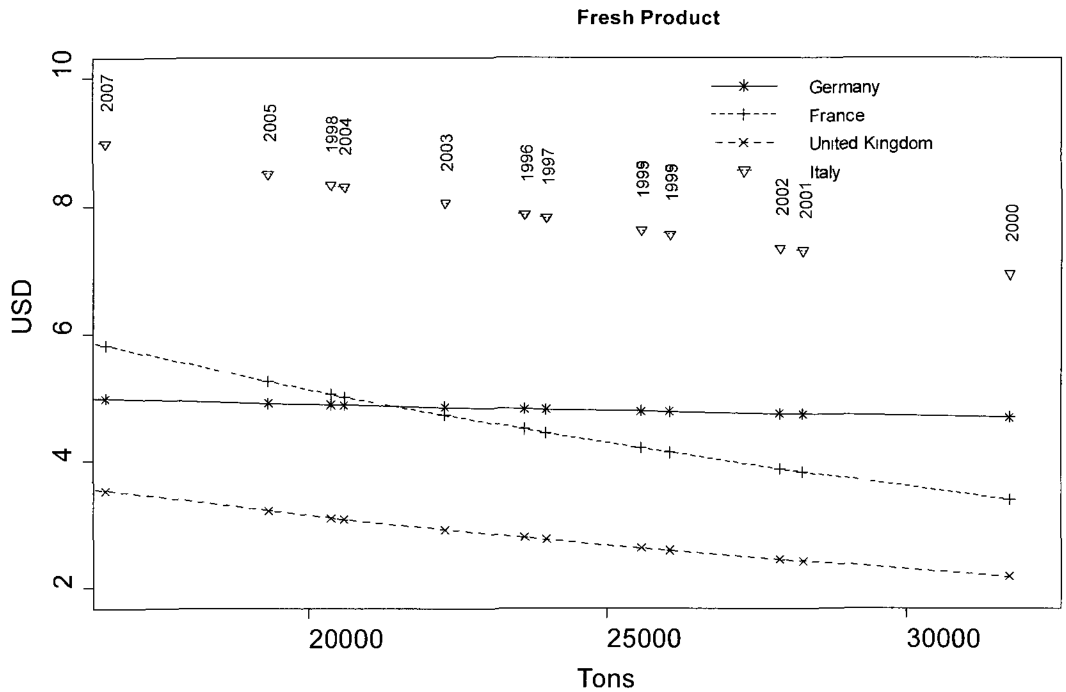



Figure 3.15 The predicted price (USD/kg) and world volume (total catch) of spiny dogfish for Germany, France, the UK, and Italy for fresh product. Numbered labels on Italian values indicate the corresponding year for each data point for all countries.

Table 3.1 US export volume (t) and associated inflation-corrected prices (USD/kg) by country and year for frozen dogfish product. Averages only include years when exported. US Customs data used to generate table.

| | Hong Kong | | China | | South Korea | | Thailand | | Japan | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Tons | USD/kg | Tons | USD/kg | Tons | USD/kg | Tons | USD/kg | Tons | USD/kg |
| 1996 | 4.34 | 9.59 | 14.37 | 14.28 | -- | -- | 76.39 | 10.45 | 212.10 | 2.90 |
| 1997 | -- | -- | -- | -- | 18.18 | 3.69 | 70.92 | 10.57 | 109.94 | 3.18 |
| 1998 | -- | -- | -- | -- | -- | -- | 12.81 | 8.05 | 479.08 | 2.31 |
| 1999 | 143.15 | 4.61 | -- | -- | -- | -- | 162.31 | 6.77 | 184.75 | 4.60 |
| 2000 | 46.78 | 2.64 | -- | -- | -- | -- | 208.47 | 3.13 | 75.98 | 2.01 |
| 2001 | 7.99 | 2.57 | -- | -- | 20.00 | 5.33 | 301.73 | 2.45 | 20.38 | 0.65 |
| 2002 | 128.36 | 2.52 | -- | -- | -- | -- | 107.07 | 2.52 | 95.37 | 2.59 |
| 2003 | 247.88 | 2.47 | -- | -- | -- | -- | 152.89 | 2.47 | 31.12 | 2.95 |
| 2004 | 94.06 | 2.40 | -- | -- | -- | -- | 103.62 | 2.45 | 18.52 | 2.05 |
| 2005 | -- | -- | 28.64 | 10.00 | -- | -- | 146.76 | 3.56 | -- | -- |
| 2006 | -- | -- | 20.30 | 14.21 | -- | -- | 101.56 | 2.45 | -- | -- |
| 2007 | -- | -- | -- | -- | -- | -- | 216.50 | 2.51 | -- | -- |
| 2008 | 16.18 | 2.17 | 58.45 | 6.98 | 16.78 | 4.48 | 94.75 | 4.32 | -- | -- |
| 2009 | -- | -- | -- | -- | 39.18 | 2.43 | 91.76 | 2.43 | -- | -- |
| Average | 84.95 | 3.79 | 30.44 | 11.37 | 23.53 | 3.98 | 131.97 | 4.58 | 136.36 | 2.58 |

Table 3.2 New Zealand export volume (t) of whole frozen dogfish by year and destination country. Data for table provided by Statistics New Zealand.

| | China | France | South Korea | Other | Total |
|---|---|---|---|---|---|
| 1995 | -- | -- | 1,718.2 | -- | 1,718.2 |
| 1996 | -- | -- | 1,832.1 | -- | 1,832.1 |
| 1997 | 7.5 | -- | 876.2 | -- | 883.7 |
| 1998 | -- | -- | 539.3 | 6.8 | 539.3 |
| 1999 | -- | -- | 1,646.7 | -- | 1,653.5 |
| 2000 | -- | -- | 1,032.0 | 0.7 | 1,032.0 |
| 2001 | -- | -- | 739.4 | - | 740.1 |
| 2002 | -- | -- | 1,199.4 | -- | 1,199.5 |
| 2003 | -- | -- | 678.7 | -- | 678.7 |
| 2004 | -- | -- | 349.8 | -- | 349.8 |
| 2005 | 108.1 | -- | 820.3 | -- | 928.4 |
| 2006 | 20.6 | -- | 1,060.2 | -- | 1,080.8 |
| 2007 | 215.0 | 44.0 | 1,019.2 | -- | 1,278.2 |
| 2008 | 6.2 | 71.4 | 637.3 | 7.5 | 714.9 |
| Total | 357.4 | 115.4 | 14,148.8 | - | 14,621.7 |

Table 3.3 Inflation corrected average price (USD/kg) and standard deviation (SD) of frozen non-headed-or-gutted dogfish exported from New Zealand. Averages exclude years without export. Data for table provided by Statistics New Zealand

| | China | France | South Korea |
|---|---|---|---|
| 1995 | -- | -- | 0.56 |
| 1996 | -- | -- | 0.52 |
| 1997 | 0.57 | -- | 0.52 |
| 1998 | -- | -- | 0.50 |
| 1999 | -- | -- | 0.53 |
| 2000 | -- | -- | 0.42 |
| 2001 | -- | -- | 0.44 |
| 2002 | -- | -- | 0.46 |
| 2003 | -- | -- | 0.55 |
| 2004 | -- | -- | 0.42 |
| 2005 | 1.52 | -- | 0.54 |
| 2006 | 1.01 | -- | 0.77 |
| 2007 | 0.34 | 2.24 | 0.75 |
| 2008 | 0.27 | 2.35 | 0.65 |
| Average | 0.74 | 2.29 | 0.54 |
| SD | 0.52 | 0.08 | 0.11 |

Table 3.4 Tons of frozen headed-and-gutted dogfish exported from New Zealand. Countries in the "other" category receive small sporadic imports and include Austrailia, Bulgaria, China, Cyprus, Fiji, Hong Kong, Indonesia, Latvia, Malaysia, Russia, and Singapore. No export was reported for 1996. Data for table provided by Statistics New Zealand

| | 1995 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Belgium | -- | -- | -- | -- | 1.0 | 3.0 | -- | -- | -- | -- | 0.4 | 21.7 | 15.0 | 41.0 |
| Denmark | -- | 16.4 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 32.6 | 13.2 | 62.2 |
| France | 10.5 | -- | -- | -- | 11.0 | 13.6 | -- | 36.9 | 90 | 79.9 | 101 | 29.3 | 13.8 | 385.9 |
| Germany | -- | -- | -- | 3.2 | 25.2 | 59.9 | 14.1 | -- | 2.5 | -- | 2.1 | 24.1 | 19.7 | 150.8 |
| South Korea | 1.6 | -- | 0 | -- | 36.6 | -- | 70.0 | -- | 0.4 | -- | -- | -- | -- | 108.5 |
| Italy | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 28.4 | -- | 28.4 |
| Japan | 7.9 | -- | 0.1 | -- | 6.1 | 0.1 | 1.2 | -- | -- | -- | -- | -- | -- | 15.4 |
| Thailand | -- | -- | -- | -- | -- | 28.7 | 25.9 | <0.1 | -- | -- | -- | -- | -- | 54.6 |
| UK | -- | -- | -- | -- | 5.4 | -- | 10.9 | 5.1 | -- | 10.1 | -- | -- | -- | 31.3 |
| Other | 16.6 | -- | 0.2 | -- | 6.1 | 28.7 | 37 | 50.7 | 9.1 | 7.5 | 17.1 | 35 | 2.5 | 210.6 |
| Yearly Total | 36.6 | 16.4 | 0.2 | 3.2 | 91.3 | 134 | 159 | 92.7 | 102 | 97.5 | 120 | 171 | 64.2 | 1,088.60 |

Table 3.5 Average price average price (USD/kg) and standard deviation (SD) for frozen headed-or-gutted dogfish exported from New Zealand. Averages exclude years without export. Data for table provided by Statistics New Zealand

| | 1995 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Belgium | -- | -- | -- | -- | 3.28 | 2.48 | -- | -- | -- | -- | 2.91 | 2.38 | 2.01 | 2.61 |
| Denmark | -- | 0.40 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2.30 | 1.52 | 1.41 |
| France | 1.70 | -- | -- | -- | 1.88 | 1.81 | -- | 1.75 | 2.33 | 2.59 | 2.64 | 2.56 | 2.85 | 2.23 |
| Germany | -- | -- | -- | 5.73 | 10.36 | 5.92 | 3.79 | -- | 2.46 | -- | 2.23 | 2.86 | 2.56 | 4.49 |
| South Korea | 1.66 | -- | 0.50 | -- | 0.54 | -- | 0.88 | -- | 0.34 | -- | -- | -- | -- | 0.78 |
| Italy | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2.90 | -- | 2.90 |
| Japan | 3.82 | -- | 0.28 | -- | 3.37 | 3.64 | 0.54 | -- | -- | -- | -- | -- | -- | 2.33 |
| Thailand | -- | -- | -- | -- | -- | 0.35 | 0.74 | 2.81 | -- | -- | -- | -- | -- | 1.30 |
| UK | -- | -- | -- | -- | 4.31 | -- | 2.21 | 2.34 | -- | 3.26 | -- | -- | -- | 3.03 |
| Average | 2.39 | 0.30 | 0.39 | 5.73 | 3.96 | 2.84 | 1.63 | 2.30 | 1.71 | 2.93 | 2.60 | 2.60 | 2.24 | 2.34 |
| SD | 1.23 | -- | 0.16 | -- | 1.42 | 1.29 | 0.24 | -- | 1.40 | -- | -- | -- | -- | 0.87 |

Table 3.6 Export volume (t) of frozen non-headed-or-gutted dogfish from New Zealand by destination country and year. Countries in the "other" category receive small and sporadic imports. These countries are Australia, Bulgaria, Canada, China, Denmark, Japan, Netherlands, Portugal, Serbia, Slovenia, South Africa, Spain, Taiwan, and Viet Nam. Data for table provided by Statistics New Zealand

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Belgium | -- | -- | -- | -- | 15.6 | 40.7 | 95.4 | 165.9 | 50.8 | 48.3 | 149.8 | 151.5 | 40.8 | 13.3 | 772.0 |
| France | 6.8 | -- | -- | -- | 13.9 | -- | -- | 39.9 | 151.9 | 57.2 | 14.2 | -- | -- | -- | 283.9 |
| Germany | -- | -- | -- | -- | 4.8 | 45.6 | 49.4 | 85.9 | 93.6 | 27.8 | 71.1 | 69.5 | 23.9 | 21.2 | 492.7 |
| Hong Kong | -- | -- | -- | 8.7 | -- | -- | -- | 17.7 | 18.9 | 39.8 | 43.8 | 25.0 | 28.0 | 13.8 | 195.8 |
| Italy | -- | -- | -- | -- | 5.0 | 57.6 | 26.6 | 19.6 | 17.7 | 25.2 | 4.1 | 5.4 | 15.1 | 8.9 | 185.2 |
| South Korea | -- | 6.0 | -- | -- | 6.8 | 61.3 | -- | -- | 22.1 | 10.8 | 67.5 | 13.0 | -- | -- | 187.6 |
| Malaysia | -- | -- | -- | -- | -- | -- | <0.1 | 1.4 | 0.5 | 1.9 | 11.3 | 15.3 | 7.8 | 12.3 | 50.6 |
| Philippines | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 10.8 | 17.1 | 8.7 | 36.6 |
| Russia | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 8.7 | 138.1 | 107.5 | 254.3 |
| Singapore | -- | -- | -- | 8.8 | 13.1 | -- | -- | -- | 5.9 | 0.9 | 8.7 | 7.4 | 6.8 | 4.5 | 56.1 |
| Thailand | 10.0 | 59.1 | 11.6 | 8.1 | 13.0 | 67.4 | 41.4 | 124.7 | 44.9 | 15.8 | 4.0 | -- | -- | -- | 399.9 |
| UK | 0.2 | -- | -- | -- | -- | 6.5 | -- | 12.4 | 6.5 | 22.0 | 39.2 | 19.1 | 18.5 | 5.8 | 130.0 |
| Other | 9.5 | -- | 16.8 | -- | 21.8 | 23.2 | <0.1 | -- | 39.3 | -- | <0.1 | 17.4 | 32.4 | 33.8 | 184.9 |
| Total | 26.0 | 67.0 | 33.0 | 26.0 | 94.0 | 303.0 | 214.0 | 471.0 | 452.0 | 252.0 | 415.0 | 343.0 | 328.0 | 230.0 | 3,253.0 |

Table 3.7 Average price (USD/kg) and associated standard deviation (SD) of New Zealand exports of frozen other then whole or headed or gutted dogfish by destination country. Shading indicates high value exports to Asian countries. Averages exclude years without export. Data for table provided by Statistics New Zealand

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Belgium | -- | -- | -- | -- | 2.08 | 2.09 | 2.12 | 2.17 | 2.12 | 2.49 | 3.00 | 2.97 | 2.62 | 2.29 | 2.40 |
| France | 2.35 | -- | -- | -- | 2.82 | -- | -- | 1.86 | 2.03 | 2.61 | 2.70 | -- | -- | -- | 2.40 |
| Germany | -- | -- | -- | -- | 5.48 | 3.16 | 4.69 | 5.46 | 3.44 | 4.28 | 4.54 | 4.55 | 4.64 | 2.87 | 4.31 |
| Hong Kong | -- | -- | -- | 1.07 | -- | -- | -- | 7.28 | 8.69 | 8.59 | 11.89 | 11.33 | 12.92 | 12.09 | 9.23 |
| Italy | -- | -- | -- | -- | 2.93 | 2.63 | 2.51 | 2.62 | 1.98 | 2.47 | 2.84 | 2.90 | 3.17 | 3.35 | 2.74 |
| South Korea | -- | 0.34 | -- | -- | 0.64 | 0.54 | -- | -- | 0.61 | 0.62 | 0.78 | 0.55 | -- | -- | 0.58 |
| Malaysia | -- | -- | -- | -- | -- | -- | 7.07 | 6.08 | 7.05 | 7.59 | 9.89 | 10.15 | 12.00 | 11.78 | 8.95 |
| Philippines | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 11.29 | 12.76 | 11.29 | 11.78 |
| Russia | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 3.20 | 2.85 | 2.83 | 2.96 |
| Singapore | -- | -- | -- | 1.08 | 8.30 | -- | -- | -- | 18.40 | 10.56 | 11.62 | 11.68 | 12.76 | 13.16 | 10.94 |
| Thailand | 1.01 | 1.09 | 0.99 | 1.11 | 0.85 | 0.86 | 0.70 | 0.70 | 0.87 | 10.43 | 10.45 | -- | -- | -- | 2.64 |
| UK | 2.42 | -- | -- | -- | -- | 3.31 | -- | 2.35 | 2.31 | 2.77 | 3.16 | 3.13 | 2.81 | 2.81 | 2.79 |
| Average | 1.93 | 0.72 | 0.99 | 1.08 | 3.30 | 2.10 | 3.42 | 3.57 | 4.75 | 5.24 | 6.09 | 6.18 | 7.39 | 6.94 | 5.14 |
| SD | 0.79 | 0.53 | -- | 0.02 | 2.73 | 1.17 | 2.49 | 2.36 | 5.47 | 3.69 | 4.33 | 4.37 | 4.99 | 4.81 | 3.91 |

Table 3.8 Goodness of fit statistics for the fresh and frozen models, including the intercept only model (null model). $SD_r$ is the standard deviation of the random effects, and $SD_e$ is the standard deviation for residual error.

| | Fresh | | | | Frozen | | | |
|---|---|---|---|---|---|---|---|---|
| | AIC | BIC | $SD_r$ | $SD_e$ | AIC | BIC | $SD_r$ | $SD_e$ |
| Model 1 | 226.04 | 231.84 | 0.00006 | 2.01 | 97.25 | 103.05 | 0.36 | 0.50 |
| Model 2 | 222.69 | 230.34 | 0.00006 | 1.98 | 91.53 | 99.18 | 0.22 | 0.50 |
| Model 3 | 107.77 | 125.61 | 0.00004 | 0.60 | 70.39 | 88.23 | 0.28 | 0.33 |
| Model 4 | 104.18 | 121.74 | -- | 0.60 | 71.3 | 88.90 | -- | 0.44 |

Table 3.9 Summary of the estimated coefficients and associated statistics for model 2 (frozen product) and model 3 (fresh product).

| Frozen Product (Model 3) | Coefficient | Std. Error | t-value | p-value |
|---|---|---|---|---|
| Intercept | 33.24 | 10.52 | 3.16 | 0.0034 |
| log(t) | -1.81 | 0.62 | -2.91 | 0.0142 |
| Germany | -4.04 | 11.20 | -0.36 | 0.72 |
| Italy | -17.09 | 11.20 | -1.53 | 0.14 |
| UK | -2.06 | 11.20 | -0.18 | 0.86 |
| France | - | - | - | - |
| Germany *log (t) | 0.25 | 0.66 | 0.38 | 0.70 |
| Italy* log (t) | 1.02 | 0.66 | 1.54 | 0.13 |
| UK*log (t) | 0.17 | 0.66 | 0.26 | 0.80 |
| France * log (t) | - | - | - | - |
| **Fresh Product (Model 4)** | **Coefficient** | **Std. Error** | **t-value** | **p-value** |
| Intercept | 68.00 | 14.42 | 4.72 | <0.001 |
| log(t) | -3.74 | 0.85 | -4.40 | <0.001 |
| Germany | -55.33 | 20.40 | -2.71 | 0.01 |
| Italy | -6.28 | 20.40 | -0.31 | 0.76 |
| UK | -29.66 | 20.40 | -1.45 | 0.15 |
| France | - | - | - | - |
| Germany * log(t) | 3.28 | 1.20 | 2.72 | 0.01 |
| Italy*log (t) | 0.57 | 1.20 | 0.47 | 0.64 |
| UK*log (t) | 1.65 | 1.20 | 1.37 | 0.18 |
| France * log (t) | - | - | - | - |

# Chapter 4 Policy Analysis for a Prospective Fishery for Spiny Dogfish in the Gulf of Alaska[1]

## 4.1 Abstract

Spiny dogfish (*Squalus sucklei*) is a common species caught incidentally in Alaskan trawl, longline, and salmon fisheries. Markets for dogfish (mainly *Squalus sucklei* and *S. acanthias*) exist in Europe and Asia, but Alaskan fishers have been slow to supply these markets. The purpose of this paper is to describe historical dogfish harvests in Alaska and provide an analysis of potential harvest given the current and future regulatory environment, including suggestions for improving marketing efforts in Alaska. Regulations currently allow dogfish to be retained in proportion to the amount of target species retained in a directed fishery. This specification will not result in significant retention of dogfish unless ex-vessel prices dramatically increase relative to target species. Even with an increased ex-vessel value, few vessels may be able to capitalize on dogfish revenue due to restrictions on harvest of bycatch species and limited access programs for vessels focusing on other, more valuable target species. Substantial marketing efforts by the Alaska seafood industry are necessary to establish dogfish markets leading to increased ex-vessel prices. A robust dogfish market in Alaska is unlikely to occur unless regulations allow directed fishing. Such a regulatory change may create incentives to use dogfish as a guise to harvest other, more valuable species under regulations for bycatch

[1] Gasper, J. R., G .H. Kruse, J. Greenberg, and Q. Fong. (In prep). Policy Analysis for a Prospective Fishery for Spiny Dogfish in the Gulf of Alaska. Prepared for submission to Fisheries Bulletin.

retention allowances. In developing management options, agencies must establish target and limit reference points for fishing mortality commensurate with the vulnerability of this species to overfishing.

## 4.2 Introduction

Dogfish (mainly *Squalus acanthias* or *S. suckleyi*) comprises a group of sharks that are common to fish markets in the United Kingdom (UK), Germany, China, South Korea, and France (Gasper et al. in prep b). Historically, dogfish supplied to these markets originated primarily from the east and west coasts of the United States (US), Canada, and New Zealand, and Atlantic waters off Europe. Stock declines during the late 1990s and 2000s in the northeast and northwest Atlantic reduced both the supply and importance of dogfish in whitefish markets (Gasper et al. in prep b).

Depletion of dogfish stocks led various environmental groups and regulatory agencies to take action against dogfish trade. Several unsuccessful attempts were made to restrict trade under the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES) during the 2000s (CITES 2004, CITES 2007, CITES 2010). Environmental organizations leveraged media attention on overfishing to discourage consumption of dogfish products in Europe, particularly for fish and chips in the UK (e.g., Gray 2008, Gray 2010). For example, the Monterey Bay Aquarium's (MBA) Seafood Watch Program publishes information about sustainable seafood choices. The MBA program recommends that consumers avoid dogfish due to overfishing, despite US stocks not being overfished under Magnuson-Stevens Fishery Conservation and Management Act (MSA) in 2011 (MBA 2011).

Synergy between stock collapses, poor publicity, and lack of sustainable labeling likely contributed to lost market share for dogfish during the 2000s (Gasper et al. in prep b).

In an effort to regain market share, stakeholders invested in marketing and sustainable eco-labeling of dogfish. Fishers on the US east coast and the west coast of Canada (primary sources of market supply) sought sustainable certification under the Marine Stewardship Certification Program (MSC, MSC 2010a, MSC 2011). Labeling under the MSC provides a third-party eco-label and product branding. Stakeholders report that MSC labeling improves prices and increases market accessibility due to reduced import tariffs (e.g., western Australian Rock Lobster) and alleviating consumer concerns about sustainability, particularly in European markets (MSC 2010b). Unfortunately, these impacts are difficult to distinguish from general market behavior and other regulatory factors that influence sustainability and economic efficiency (e.g., catch share programs, MSC 2010b). Regardless, obtaining sustainable seafood is important to many Europeans, a major consumer of dogfish (DEFRA 2011). Despite the need for sustainable sources of dogfish, Alaska has not been a significant supplier in the modern era.

Dogfish populations off Alaska are not overfished as defined in the MSA. The dogfish resource in Alaska is underutilized despite being a common species. For example, none of the 6,197 t federal catch limit for 2011 was used to supply dogfish markets. Export channels from Alaska are not established, fishers and processors are not accustomed to handling dogfish, and dogfish do not carry a third-party sustainable label. Thus, the market potential for Alaska dogfish is currently unknown.

A comprehensive view of economic barriers to the harvest of dogfish in Alaska is required to understand marketing issues. These barriers include regulations that restrict harvest, costs associated with processing and capture, and investment in marketing of an Alaskan product. In this paper, we first take a look at historical fisheries in Alaska to understand past successes and failures with dogfish markets. We then examine the current regulatory environment for the State of Alaska (State) and US federal government, with a focus on the Gulf of Alaska (GOA) longline fishery. We analyze the feasibility of a bycatch-only fishery in the current regulatory environment and potential future directed fishery. Included is a discussion on product quality issues and recommendations for future marketing and management measures.

## 4.3 Historical Alaska Dogfish Fisheries: pre-2000

Historical commercial dogfish harvests in waters off Alaska have been small and sporadic, with ephemeral markets due to low prices, high harvest cost and inability to consistently catch dogfish. The first recorded commercial sales of dogfish occurred in 1910 when Revilla Reduction Works of Ketchikan, Alaska, reduced shark livers to oil (Roppel 1977; Ketchen et al. 1983). Revilla could not secure adequate supply of shark and dogfish livers to operate and abandoned their business in 1911 (Roppel 1986). Demand for vitamin A increased during World War II, resulting in an increased demand for vitamin rich shark livers (Ketchen et al. 1983). The Dawes Products Company of Chicago leased a building on the Ketchikan cold storage dock

(Figure 4.1) where a subsidiary, the Alaska Fish Oil Extractors (Figure 4.2), processed Pacific halibut *(Hipploglossus stenolepis)* and sablefish (*Anoplopoma fimbria*) livers and viscera and shark livers (including dogfish) to produce vitamin A (Roppel 1986). Processing started in 1941 (Roppel 1986) and likely continued until 1949, given historical catch data in Southeast Alaska and public records (DOI 1958).

Alaska Fish Oil Extractors is the only known major processor in southeastern Alaska accepting dogfish livers and likely accounts for most of the dogfish harvest (Table 4.1). Production peaked in 1946 at approximately 6.2 million pounds (2,812 t) of catch, of which 17,163 gallons (64,969 liters) of oil worth an estimated 78.65 USD per gallon was produced (DOI 1958). Only small amounts of harvest occurred between 1950 and 1954 and by 1955 the dogfish harvest ceased. The disposition of dogfish during these later years is unknown.

Very little information is available on dogfish harvest between 1958 and 1992, but it is likely that dogfish utilization in Alaska had a long hiatus until the late 1990s and 2000s. During the late 1990s a perception of increased dogfish abundance (e.g., Wright and Hulbert 2000) in the GOA increased interest in creating fishery revenues and employment by utilizing the resource.

## 4.4 Dogfish Catch in Waters off Alaska: 2000-2010

In contemporary fisheries, dogfish are caught incidental to groundfish and salmon fisheries in the GOA. Most incidental dogfish catch occurs in the groundfish longline fishery in the central and eastern GOA (areas 650, 640, 630, 620; Figure 4.3). Catch accounting estimates of discards started in 2003; catch peaked in 2006 at

1,232 t for all gear types with an average of 644 t during 2003 to 2010 (Table 4.2). No discernable trend is apparent, given a second peak of 1,085 t in 2009 and low catches in 2003, 2004, and 2010, indicating high year-to-year variability. The catch shown in Table 4.2 does not include incidental catches in the halibut Individual Fishing Quota (IFQ) fishery and State salmon fisheries, neither of which carry onboard observers, as well as catch in federal reporting areas 659 or 649, which are confidential due to a low number of participating vessels. The halibut IFQ fishery is a substantial inshore longline fishery that occurs throughout the entire GOA with effort particularly concentrated in nearshore waters of the eastern GOA and waters near Kodiak and Cook Inlet. State salmon fisheries are widespread throughout the GOA inshore areas and include troll gear, drift and set gillnets, and purse seines (ADFG 2010). With the exception of troll gear, salmon fisheries operate during the summer months when salmon are returning to their natal river.

The amount of incidental catch in State salmon fisheries is largely unknown, with the exception of Yakutat Bay area where, as previously discussed, a set-gillnet fishery for dogfish occurred. A small dogfish fishery using set gillnets, otherwise used to fish for sockeye salmon *(Oncorhynchus nerka)*, developed in Yakutat Bay between 2001 and 2008, but harvest amounts were small and sporadic, with harvest occurring in 2001, 2002, 2006, 2007, and 2008. In 2004 and 2005, minor amounts of dogfish caught in federal groundfish fisheries were landed in Kodiak or Seward. Most landed dogfish was processed into meal, but small amounts (<10 t) were headed and gutted in 2006 and processed and reported as eastern cut dogfish or retained as whole product destined for European fish and chip markets in 2006 and 2007. Meal is a low value product that generally has very low ex-vessel value (if any) and likely reflects the need of the processing plant to dispose of fish not discarded at sea. Almost all meal products were harvested using trawl gear and most non-meal products were harvested using longline gear. Confidentiality restrictions prevent the reporting of volumes, and the ex-vessel price for these products is unknown.

However, even in the set-gillnet fishery there were unknown discards amounts, particularly since fishers were reportedly high grading to obtain sharks larger than 3.6 kg (Tribuzio[2]). Some fishermen reportedly increased their mesh sizes to catch larger dogfish. Yakutat Bay is also unique in that a number of studies conducted in the area have suggested particularly high concentrations of dogfish. The University of Alaska Fairbanks and NMFS sampled waters off Yakutat Bay using sport fishing gear. These sampling efforts showed very high catch rates (1.8-3.9 dogfish per rod hour) during the months of July, August, and September (Tribuzio 2009; Tribuzio et al. 2010). However a single summer of sampling in 2008 (May-September) by the Marine Mammal Observer Program (Manly 2009) in the Situk River estuary resulted in very low numbers of sampled dogfish, which corresponds with harvest data indicating most retained dogfish originated outside the estuary towards Yakutat Bay (Woods[3]). GOA-wide spatial modeling of dogfish abundance

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[2] Tribuzio, C.A. 2011. National Marine Fisheries Service, Alaska Fishery Science Center Auke Bay Laboratory. Juneau, Alaska. Personal commun.
[3] Woods, G. 2010. Alaska Department of Fish and Game, Commercial Fisheries Division. Yakutat, Alaska. Personal commun.

also suggests high concentrations of dogfish in the Yakutat area (Gasper et al. in prep a).

## 4.5 Current Harvesting Regulations

Dogfish in the GOA are assumed to be a single population that ranges throughout State and federal waters. As a result, mortality from both federal and State fisheries are considered in the federal stock assessment process (Tribuzio et al. 2010). Between 1998 and 2010, dogfish were federally managed in an assemblage category in the GOA groundfish fishery management plan (FMP) that included skates (until 2003, family Rajidae), sculpins (species of the genera *Mcoxocephalus, Hemitripteru,* and *Hemilepidotus)*, all sharks (mainly *Lamina ditropos*, *S. suckeyi*, and *Somniosus pacificus*), squids (order Teuthoidea), and octopuses (largely *Enteroctopus dőfleini)*. A single total allowable catch (TAC) was set for the entire category such that it was equal to 5% of the total TACs for all other groundfish. This was modified in 2008 under GOA FMP Amendment 79 such that an acceptable biological catch (ABC) and overfishing level (OFL) could be determined for the "Other Species Complex" (NPFMC 2008). The OFL is the estimate of the catch, above which maximum sustainable yield is jeopardized and overfishing occurred or is occurring. These limits were based on the specifications of the component species in the Other Species Complex. For spiny dogfish, the OFL specification, called Tier 6 assessment in the GOA FMP, was based on a 10-year average (1997-2007) of catch and the ABC was set at 75% of the OFL (Tribuzio et al. 2010). The ABC accounts for scientific uncertainty in the estimate of OFL. The TAC is set equal to or less than the ABC for a given species in any one year.

The MSA as amended by the Management Reauthorization Act of 2006, provides requirements to prevent and end overfishing. Moreover, the reauthorization resulted in revised guidelines to National Standard 1 (74 FR 3178) requiring annual catch limits (ACL) and accountability measures for federal fisheries within fishery management plans. To comply with the regulatory requirements, the North Pacific Fishery Management Council (Council) dissolved the Other Species Complex and created separate stock complex categories for octopus, sharks, and sculpins. This change resulted in establishment of the TAC, ABC, and OFL individually for these groups during an annual harvest specification process. Creating a shark category was an important conservation action taken by the Council and NMFS. This established a limit that addressed the biological vulnerabilities of dogfish, particularly their low fecundity, late maturation, data-poor assessments, and vulnerability to various gears used in other GOA fisheries (Tribuzio and Kruse in press). The Council also recommended placing sharks on bycatch-only status, which prohibits directed fishing. This recommendation was implemented for the 2011 fishery and ensured conservative management of the species.

Previously, sharks had been under the previously described Tier 6 assessment based on historical catch, but the breakout provided opportunity for review of assessment methods for dogfish by the Council's GOA Groundfish Plan Team and their Scientific and Statistical Committee (SSC) in 2010. The SSC recommend a new assessment method for dogfish for 2011. The method calculates the OFL as the product of a biomass point estimate and an indirectly estimated natural mortality rate of 0.097 (Tribuzio et al. 2010). Setting fishing mortality rate (F) equal to an estimated natural mortality rate (M) is a control measure used in fisheries throughout the world, particularly data-poor fisheries. However, setting fishing harvest at M does not consider other sources of uncertainty, such as management implementation error, assessment imprecision associated with stock fluctuation, unreported catches (e.g., discard mortality in non-observed fisheries), or fishery closure before the TAC is exceeded. Federal stock assessments attempt to incorporate uncertainty by using F=M as a limit reference point (OFL) and the ABC is conservatively set 25% below that point. The biomass point estimate is based on an average of the three most recent biennial trawl survey estimates of dogfish biomass. The survey underestimates dogfish biomass because it uses a bottom trawl although dogfish are found throughout the water column. Thus, the current use of bottom trawl surveys instills additional conservatism in the catch specifications.

As a matter of practice, the biomass assessment method increased the OFL and ABC in comparison with the Tier 6 assessment method, because historical catches have been very low compared to biomass levels. In 2011, a dogfish-specific specification was set for the first time and the corresponding ABC and OFL were 6,197 t and 8,262 t, respectively. The TAC for spiny dogfish in 2011 was set equal to the ABC (6,197 t). This was a 1,697 t increase above the 4,500 t federal TAC for the Other Species Complex annually set since 2008.

The federal stock assessment for dogfish considers the biomass and catches (including discards) of dogfish in State waters, but catches in State fisheries do not currently count against the TAC, ABC, or OFL (Tribuzio et al. 2010). State catch only counts against the TAC, ABC or OFL in parallel fisheries (e.g., Pacific cod, *Gadus macrocephalus*, i.e., those in which the State elects catch from State waters to apply against federal limits). The State does not conduct its own dogfish stock assessment.

All sharks are prohibited to directed fishing (bycatch status only) in federal waters and thus retention of the species is subject to maximum retainable amounts (MRAs). Both retained and discarded catch accrues against the annual GOA-wide TAC specification that, once reached, results in fishery closures if necessary. At-sea discards are estimated using a combination of at-sea observer information and landing or production information (Cahalan et al. 2010). For fisheries open to directed fishing, inseason management may put the fishery in "bycatch" or "prohibited status" prior to closure, thus allowing target fisheries to continue without closure. "Bycatch status" allows some retention under MRA regulations, while "prohibited status" prohibits any retention of the species. MRA regulations allow a species (or group) closed to directed fishing to be retained up to a percentage, specified in federal regulation, of the retained weight of a species (or group) open to directed fishing (Figure 4.4). The MRA accounting in the GOA occurs instantaneously such that a vessel is prohibited from exceeding the MRA at any time. Prohibited status requires any catch to be discarded and is necessary to ensure that TACs are not exceeded. This allows limited retention of species closed to directed fishing and reduces the pace of fishing. Retainable percentages play an important role in influencing discard rates and meeting management objectives. Reducing the pace of fishing helps control harvest of biologically sensitive species and controls harvest in critical habitat areas. For example, in some situations, MRAs alleviate allocation conflicts and may reduce regulatory discards.

When dogfish were moved from the Other Species Complex into a shark complex in 2011, the MRA regulations remained unchanged. Retainable percentages for federal waters (3-200 nmi) apply to the aggregate of retained species in the Other Species Complex. The MRA limit for the Other Species Complex is 20% of the weight of each retained species open for directed fishing (called a "basis species").

Dogfish are not allowed for directed fishing in State waters (0-3 miles) unless an Alaska Department of Fish and Game commissioner's permit is obtained or catch occurred in the Yakutat set net fishery, where regulations already allow directed fishing. However, State regulations allow incidental retention of dogfish. These fisheries generally have similar retention requirements as Federal MRA requirements, except in the Southeastern District of State waters where dogfish-specific retention limits are established (Table 4.3). For example, retention of dogfish in salmon troll fisheries and longline fisheries for demersal shelf rockfish (DSR) assemblage and longline sablefish are limited to 35% of the basis species (Table 4.3). Other fisheries, such as lingcod (*Ophiodon elongates*) fisheries, jig gear DSR, the black rockfish *(Sebastes melanops)* fishery, and the small Southern Southeast Inside pot gear sablefish fishery may retain dogfish up to 20% of their directed species catch. Vessels harvesting IFQ halibut in Southeastern District waters are prohibited from taking more than 35% of the retained halibut weight in dogfish unless they fished in both State and federal waters during a single trip, which results in the more restrictive retention regulation taking precedence. Both State and federal waters have areas where commercial groundfish fishing is prohibited (e.g., Edgecumbe Pinnacles Marine Reserve off Sitka, Alaska) or certain gear types are restricted, such as a trawl gear prohibition for both State and federal waters in southeastern Alaska.

State areas without dogfish-specific retention requirements differ from federal MRAs in that the 20% retention allowance is based on the aggregate of all species closed to directed fishing (Table 4.3). This is an important distinction because commonly retained species are counted against the State limit, resulting in a more restrictive limit. Specifically, federal MRA regulations for dogfish apply to species in the "other category" while State retention includes all species closed to directed fishing.

## 4.6 Current Processing Regulations

The processing of sharks and dogfish, in particular, is governed by State and federal regulations. The primary products for sharks are fins and meat, with fins being a highly controversial issue. Dogfish fins are sold in Chinese markets and are a potential revenue stream for Alaskan fisheries. The methods used to harvest fins are governed by both State and federal regulations depending on the jurisdiction where dogfish are harvested. State of Alaska regulations as 5 AAC 28.084(c) state:

*A person that retains any species of shark as bycatch and sells or retains any species of shark, must sell or utilize the shark. All harvested sharks must have fins, head, and tail attached at the time of sale. In this subsection, "utilize" means use of the flesh of the shark for human consumption, for reduction to meal for production of food for animals or fish, for bait, or for scientific, display, or educational purposes.*

Section 307 of the MSA describes regulations for shark finning in federal fisheries. This section was recently amended by the Shark Conservation Act (Act) of 2010 to prohibit the following:

- removal of fins (including the tail) from a shark carcass while a vessel is at sea;
- a person from having custody, control, or possession of any fin aboard a fishing vessel unless the fin is naturally attached to the corresponding carcass;
- to transfer a fin from one vessel to another vessel at-sea, or receive any such fin in transfer without the fin naturally attached to the corresponding carcass; or
- land a fin without the fin being naturally attached to the corresponding carcass or to land any shark carcass without fins naturally attached.

The Act also provides a rebuttable presumption and defined “naturally attached” as being “attached to the corresponding shark carcass through some portion of uncut skin.”

Neither State nor federal regulations allow fins to be detached by the harvesting vessel. State regulations go a step further and do not allow the shark to be headed while it is at-sea. The two laws differ about whether fins can be processed at-sea. Federal regulations prohibit at-sea processing of fins or the transfer of fins in federal waters. However, State regulations specify fins must be attached at the time of "sale," which means a catcher vessel could sell whole sharks to an at-sea processor who then would process them into fin products while at-sea in State waters. Regardless, fins can be processed by shoreside plants under either State or Federal regulations.

## 4.7 Management Scenarios

### 4.7.1 Status quo: Incidental Catch Fishery

We conducted an analysis to examine harvest amounts for all federal longline fisheries between 2008 and 2010 in which we estimated potential harvest capacity (t) for dogfish in an MRA only fishery. This analysis calculated MRA amounts on a trip basis for each longline vessel making a shoreside landing in a federal fishery. For each landing, the basis weight was determined based on retained catch for a species that was open to directed fishing. This basis weight in turn was used to calculate the maximum amount of "other species" that could be retained based on the 20% MRA promulgated in federal regulations (Table 10 to part 50 CFR 679). The dates associated with directed fishing openings and closures for hook-and-line gear are published in Status of Fishery Reports available on the NMFS Alaska Region website (http://www.fakr.noaa.gov/). The analysis was only conducted for shoreside processors and not catcher processors due to an inability to match available production data with fishery openings and closures. The problem is that production report information has been reported historically on a weekly rather than daily basis, which prohibits estimating MRAs due to mid-week fishery closures. Difficulty in matching trip level information resulted in an assumption that each landing report corresponds to a single trip, which is not always true. Not more than 4% of all trips comprise multiple reports. This issue does not affect total MRA calculations, but results in a small underestimate of per-trip statistics reported in this paper.

The analysis showed a considerable amount of dogfish that could be retained dogfish in a bycatch-only fishery for the shoreside fleet. Potential amounts ranged from a low of 6,993 t in 2010 to a high of 7,481 t in 2008 (Table 4.4). These amounts are near a hypothetical Tier 5 spiny dogfish ABC in 2008 and 2009, but well above the ABC and near the OFL in 2010 (Table 4.5). Full utilization of the MRA is not likely due to the impracticality of harvesting every last kg and, more importantly, economic incentives associated with harvesting dogfish. Incentives to harvest dogfish under MRAs comprise the bulk of the proceeding discussion.

The analysis revealed considerable variation between areas and fisheries. The halibut IFQ fishery has the largest potential for retention, with the MRAs highest in the Central GOA (CGOA; Figure 4.5). The sablefish and Pacific cod fisheries in the CGOA have similar harvest potential, but are both considerably less than the halibut IFQ fishery (Figure 4.6). In the Eastern GOA (EGOA), sablefish and halibut IFQ fishing dominate and thus there is comparatively little harvest of other groundfish species. These figures likely underestimate the potential MRA associated with sablefish in the EGOA due to State sablefish fisheries in southeastern Alaska and Prince William Sound not being included in the analysis. However, dogfish abundance in the inside waters of southeastern Alaska and at the depth where sablefish occur is generally low and sablefish harvest is low (Gasper et al. in prep a). An important caveat is that this analysis assumes 20% retention for dogfish only, but in reality dogfish harvest is limited by the retention of other incidental groundfish.

Vessels between 30 and 60 feet length overall had the highest potential MRA volumes for the season. Smaller vessels had less potential MRA, while larger vessels had considerable MRA capability, but there were fewer large harvesting vessels and thus overall volume was smaller (Figure 4.5). Small vessels generally had low per trip MRA allowances in comparison with larger vessels. For example, the per-trip volume of MRA available for the vessels less than 30 ft ranges from medians of 0.07 (t) per trip to 0.16 (t) per trip. Vessels between 60 and 90 feet had a much larger per trip capacity ranging between medians of 1.36 (t) per trip to 2.44 (t) per trip, with the largest capacity in the CGOA (Table 4.6). All areas had considerable between-trip variation in the amount of MRA species that could be harvested. This variation is a result of the basis species that is harvested per trip and reflects harvest volumes in the target fishery.

Despite smaller vessels comprising most of the total harvest, vessels larger than 50' LOA had sufficient IFQ harvest amounts to generate substantial MRA revenue, with annual values above 10,000 USD (assuming a 0.15 USD ex-vessel price). Ex-vessel prices have been reported as low as 0.07 USD in Alaska (Woods[3]), but the low price is partially attributed to an immature market for dogfish in Alaska. So, the assumed 0.15 USD per pound is consistent with reported ex-vessel prices for the Atlantic. Regardless, the range of landing volume due to IFQ, fishing seasons, and vessel sizes resulted in considerable variation in the amount of revenue generated in major ports (Figure 4.7).

Fisheries with shorter seasons generally had lower trip volumes than IFQ fisheries. A possible reason for the difference is that the IFQ sablefish and halibut program allow operators to optimize product quality, ex-vessel price, and costs associated with distance traveled and trip duration. This may result in trips with higher volume, which is particularly evident in the WGOA and CGOA where a relatively short Pacific cod season is prosecuted alongside a 9-month IFQ halibut and sablefish fishery. The discrepancy of the predicted MRA between the two fisheries is large (Figure 4.6).

An MRA-only fishery would likely not result in large spatial changes in the longline fleet. Both the revenue generated from groundfish as well as the MRA is dependent on the volume of target species caught. Assuming the fleet is already maximizing basis species catch and the distribution of catch resembles historical patterns, the fleet would not dramatically increase harvest costs in pursuit of low value dogfish. Historically, shoreside-based longline fisheries fish in the same region as their port of delivery. For example, vessels fishing in federal reporting areas 640 and 650 deliver to ports in Southeast Alaska, whereas vessels delivering to Kodiak fish in federal areas 620 and 630 and vessels delivering to Cook Inlet or Prince William Sound (PWS) almost exclusively fish in adjacent waters (Table 4.7).

The largest overall MRA volume would include deliveries made to Kodiak, Cook Inlet, and southeastern Alaska, with large individual deliveries made in PWS. The large median delivery size in PWS reflects the relatively small number of vessels making deliveries to Valdez, Whittier, Seward, or Cordova. All ports have consistent delivery size and overall MRA volume between years (Table 4.7).

The highest concentration of dogfish occurs in the outside waters of Southeast Alaska, particularly outside water ports of Yakutat and Sitka, and waters near Kodiak (Tribuzio et al. 2010; Gasper et al. in prep a). Vessels delivering to ports in inside waters of Southeast Alaska (e.g., Petersburg and Juneau), would have to travel to outside waters or southern Southeast Alaska to find sufficient quantities of dogfish (Gasper et al. in prep a). Kodiak has the second highest MRA potential, suggesting it could be a major port of delivery to dogfish.

In conclusion, the majority of the fishing fleet would likely not see a dramatic increase in revenue from a dogfish MRA fishery. Ex-vessel value for dogfish in comparison with other Alaskan species (2007-2009) is very low, making small deliveries uneconomical (Table 4.8). For vessels that have large halibut and sablefish IFQ amounts from which to base an MRA, retention would depend on a number of factors, including the availability of dogfish, the degree to which capturing dogfish interferes with target species catch, hold capacity and ability to maintain product quality, and whether there is a dogfish buyer that is convenient to target species offload (i.e., offloading at multiple ports may increase costs). Vessels fishing in the WGOA would likely not see benefits from a dogfish fishery due to a lack of high dogfish abundance and low incentive to harvest dogfish during the lucrative Pacific cod and walleye pollock *(Theragra chalcogramma)* fisheries. These fisheries have short seasonal openings in which vessels are in somewhat of a race to harvest target species. The largest benefits would be vessels fishing near the ports of Yakutat, Kodiak, and southeastern Alaska. These regions have high concentrations of dogfish near areas where halibut and sablefish IFQ are harvested. Moreover, dogfish are less likely to be caught in deeper waters where sablefish occurs, which reduces potential depredation of longline gear while sablefish fishing.

Here, we have not focused on longline catcher processors, but there are a small number of longline processing vessels operating in the GOA that could provide very high quality dogfish products. The ability for these vessels to operate in an MRA fisheries is unknown, but if IFQ species basis amounts are adequate to support sufficient dogfish volume and offset costs, they could provide very high quality frozen product. Catcher processors must consider the costs associated with processor configuration, plate freezer space, and space for products. Regardless, any MRA fishery must balance costs associated with harvesting dogfish and the potential decrease in target species harvest. In addition to assuming an ex-vessel price from a non-Alaska fishery, this analysis was not able to characterize other issues such as "latent" hold storage capacity for transporting dogfish to processors, and costs of handling and capturing dogfish.

### 4.7.2 Directed Dogfish Fishery

A directed dogfish fishery would require the shark group to be moved from "bycatch status" to an "open status" for directed fishing. This would allow vessels to target dogfish (and other sharks). Currently, dogfish are part of the shark complex TAC and thus a directed dogfish fishery is also influenced by the amount of total shark catch (retained and discarded) accruing towards the shark complex. Inseason managers would monitor the shark TAC to insure enough incidental catch is available for non-directed fisheries and that the total shark complex's catch does not exceed the TAC. If incidental catch became a problem, NMFS might close or spatially limit directed fisheries and require all shark species be discarded (known as prohibited status). Responsive closure is particularly important for dogfish due their biological vulnerability to over-harvest.

The State of Alaska and its regulatory body, the Alaska Board of Fisheries, would need to promulgate regulations to allow for directed fishing in State waters. The regulations could be targeted at specific geographical areas and limit the allowable amount of harvest. Federal stock assessments would need to consider mortality in State waters because dogfish are believed to be a single population in Alaska. Separate state-specific assessments could be conducted, but the two assessments would need to be integrated to provide a consistent stock-wide biomass assessment.

A directed fishery would allow fishers to explicitly target dogfish rather than trying to optimize the catch of target species as well as dogfish. This flexibility would allow vessels to make short trips from ports with neighboring high dogfish concentrations (e.g., Yakutat), target concentrations of dogfish, fish during periods that did not interfere with fishing for valuable species, customize deliveries to meet processing and marketing needs, and potentially use MRAs to target valuable species closed to directed fishing (e.g., Pacific cod).

The benefits of a directed dogfish fishery coupled with a favorable price for dogfish and other target species could create a race for fish. This well-documented phenomenon occurs when fishers race each other to increase their individual share of the TAC before the fishery is closed. Current dogfish prices and Alaskan market conditions are not favorable for a race to fish, but investment and changes in consumer demand can quickly change incentives. Skates in the GOA are a recent example of an emerging market causing biological concern. Kodiak entrepreneurs conducted a large amount of marketing in 2001 to secure market channels for Alaska skate product (wings) and to develop appropriate gear configurations (Muse 2004). Rapid growth in the fishery was realized in 2003 due to favorable skate prices that increased ex-vessel prices from 0.05 USD/lb (0.11 USD/kg) to a high of 0.25 USD/ lb (0.55 USD/kg) in the spring of 2003, putting ex-vessel value for skates on par with Pacific cod (Muse 2004; Ormseth and Matta 2007). Fishers were also incentivized to harvest Pacific cod against the Other Species Complex basis MRA, thus allowing the harvest of cod outside of the Pacific cod season.

In response to the price incentives and the ability to harvest Pacific cod MRA, a dramatic increase of retained skates occurred between 2002 (690 t) and 2003 (3,462

t) for both longline and trawl vessels (Muse 2004; Ormseth and Matta 2007). The sudden increase in skate harvest caused conservation concerns (Reuter et al. 2010). In response, the Council amended the GOA FMP (Amendment 63) to trifurcate skates from the Other Species Complex into separate categories: the big skate (*Raja binoculata*), longnose skate (*R. rhina*), and other skates (*R. spp.*). The action created category-specific ABC, OFL, and TAC limits specified annually in the NMFS harvest specifications.

The skate fishery operated under the Other Species Complex MRA until 2004 when skates were divided into the *R. binoculata, R. rhina*, and *R.* spp. management groups. The 2003 season reportedly resulted in low quality product being put on the market, which may have degraded the Alaskan market and removed some incentive to harvest skates from 2004 to recent years (Keaton[4]). The retained catch was 1,842 t in 2004 and reached a low of 1,430 t in 2007. The corresponding CPUE also declined after 2003 (Reuter et al. 2010). Markets for Alaska skate wing products have recently become re-established and retained catch has slowly increased. Since 2007 directed fishing for skates has been closed and these species have been harvested by both longline and trawl gear as an MRA species.

As with skates, consideration should be given to groundfish that could be harvested as an MRA species under a directed dogfish fishery. If directed fishing for sharks was open, the Other Species Complex MRA of 20% could be applied to basis species listed in Table 10 to part 50 CFR 679, resulting in harvest of valuable

[4] Keaton, R. 2011. National Marine Fisheries Service, Alaska Regional Office. Juneau, Alaska. Personal commun.

groundfish such as Pacific cod, flatfish, and rockfish. Harvest of these species would also incentivize harvest of dogfish such that increasing the amount of retained dogfish would also increase the legal retainable amount of valuable groundfish species during a fishing trip. For example, trawl vessels in the GOA Rockfish Program may harvest sablefish up to the MRA. The harvest of MRA groundfish could also occur outside of the historical seasons, thus changing the distribution of fishing.

## 4.8 Market Development and Product Requirements

### 4.8.1 World Market Overview

Markets for Alaska dogfish can be segmented into two primary categories: European or Asian. The largest markets for Alaskan dogfish are well established in Europe; the United Kingdom (UK), France, Italy, and Germany have been important consumers historically. Consideration to markets in Ireland and Asia should also be provided in the marketing portfolio for Alaskan dogfish. Primary Asian markets are China for shark fins and meat exports to South Korea. Finally, a variety of specialized uses for dogfish such as medicine and education also exist. A brief description of these markets is provided below, but readers can find a detailed description on market volume and price trends in Gasper et al. (in prep b) and Lack (2006).

### 4.8.2 European Markets

In general, product forms for European markets are either fresh or chilled, and common product categories include backs or trunks with skin on or off, belly meat, or whole (gutted and headed). The market for belly meat is exclusively to meet German demand for smoked products. The other product forms are either sold in fish markets or served as fish and chips in restaurants (Gasper et al. in prep b). Potential market opportunities exist in both prepackaged meals and sale of unpackaged whole fish or backs and trunks, depending on the country. In all European markets, cod is the generally the most important whitefish species, but declines in domestic supply of cod have increased consumption in other whitefish species and reliance on imports.

Since 2003, declines in domestic supply increased the UK's reliance on imported fresh and frozen whole dogfish or backs and trunks from the US and Canada. The product is often sold as rock salmon in the UK. Despite the reliance on imports, overall trade of dogfish to the UK has declined 90% from highs in the mid-1990s of over 10,000 t when the market was active. This decline occurred despite upward trends in seafood consumption in the UK (DEFRA 2011). Consumption statistics show UK consumers eat, on average, 1.6 portions of seafood a week, with many people experiencing their seafood in a fish and chips dish (Harmon and Galloway[5]). Pacific cod, a common species in fish and chips, is the third most consumed fish species ranking behind tuna (#2) and salmon (Harmon and Galloway[5]). Dogfish consumption in the UK has likely declined due restrictions on harvest in the northwest and northeast Atlantic Ocean and North Sea, but also consumer perceptions about a lack of dogfish conservation may also have discouraged consumption (Gasper et al in prep b). Approximately 50% of the total

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[5] Harman, J., Galloway, K. 2007. Seafood: supplies, sustainability, and consumer behavior. Presentation by the UK Seafish Industry Authority. SeaFish http://www.seafish.org/media/Publications/Seafood_Supplies_SustainabilityandConsumerBehaviour_Roweett_Presentation.pdf [Accessed 1 May, 2011].

UK seafood value is consumed in the food service sector (Cappell et al. 2007) and may reflect uncertainty by consumers about cooking the fish properly, the smell, and general appearance (Harman and Galloway[5]). However, these concerns are alleviated by prepared meals, which have become more prominent in the market recently (Cappell et al. 2007). These meals are pre-prepared breaded fish or pre-packaged fresh or frozen fish ready for cooking or reheating.

The market for dogfish in Germany is small and highly specialized for the production of smoked belly flaps (*Schillerlocken*) or meat is marinated in gelatin and sold as conger eel. Demand in this market is focused on large frozen or fresh belly meat that is primarily obtained from the US and Canada. Smoke houses sell value-added dogfish directly to consumers or restaurants. However, import volume severely declined since the mid 1990s (Gasper et al. in prep b). Some of the market decline is likely due to health concerns about eating dogfish owing to mercury content, as well as conservation concerns about overfishing of shark species (Kloppmann[6]; Mercker[7]). Despite *Schillerlocken* having a very small market share, there is still a core group of consumers and 2011 retail prices for the product ranged between 29 and 35 Euros (approximately 42 to 50 USD per kg, Kloppmann[6]).

Consumption of shark meat is common in Italy (Welch et al. 2002), with fresh seafood products primarily distributed to domestic consumers by wholesale fish traders (FAO 2010). Consumption of fresh shark may explain the large import volumes of fresh product observed in Italy. France is an important exporter of dogfish

[6] Kloppmann, M. 2011. Institute of Sea Fisheries, Federal Research Institute for Rural Areas, Forestry, and Fisheries. Hamburg, Germany. Personal. commun.
[7] Mercker, F. 2009. President Arrowac Seafoods Inc. Seattle,Washington. Personal commun.

to Italy, while the US has not historically exported large volume of dogfish directly to Italy. Statistics are not clear as to whether US products bound for France are being re-exported to Italy. Domestic consumption of dogfish under the trade name *Saumonette* occurs in France for both fresh and frozen whole fish and backs. Dogfish are consumed in institutions such as hospitals, but further information on market segmentation is lacking.

Historically, dogfish were consumed in Ireland as fish and chips under the trade names of rock salmon or cape shark. In fact, elasmobranchs were not uncommon and dogfish was served along with skates, which were known as "pissy ray" due to the strong ammonia smell from uric acid (Iomaire 2006). The important fish and chip species in Ireland are Atlantic cod (*Gadus morhua*), hoki (*Macruronus novaezelandiae)*, haddock (*Melanogrammus aeglefinusi*), hake (genus *Merluccious*), and Pacific cod imported from the US. In the fresh fish market, salmon is the most popular fish species (30.6%), followed by cod (16.1%), and haddock (8.1%, BIM 2011). Seafood consumption in Ireland is estimated at 16.7 kg annually and is expected to grow in coming years (BIM 2011). Fresh or chilled fish accounted for roughly 60% of the total fish market. In recent years, more people are switching to frozen products (approximately 3%) due to a 4% increase in fresh fish prices (BIM 2011).

### 4.8.3 Asian and other markets

Asian markets are largely supplied with frozen dogfish imported from New Zealand, with smaller amounts from the US and Canada (Gasper et al. in prep b).

Dogfish pectoral and caudal fins appear to an important export commodity, but meat is also an important export to South Korea and prior to 2004, Japan. Alaskan dogfish could potentially supply the fin and meat market, but market channels between Asian countries are poorly understood and the quantity of domestic consumption and reprocessing activity is unknown. Reprocessing of whitefish species harvested in Alaska is a common practice and thus a similar situation may occur for dogfish imports from New Zealand. This is certainly the case for dogfish fins, which are not dried in any of the major dogfish capture countries. Fins are either processed from whole dogfish in Asia or cut and frozen (not dried) prior to shipment from the exporting country. These fins are almost exclusively meeting Chinese demand and a large portion of fins likely pass through wholesalers based on mainland China, Taiwan, or Hong Kong. Small amounts of dried fin products also are exported from Asia to the US and Europe (and likely other countries) for specialized cuisine.

Finally dogfish cartilage and meat is also sold in smaller specialized markets. One such product is fish meal, which consists of rendered dogfish and other fish species that are sold as animal feed or fertilizer. Alaska currently produces meal, but dogfish are not targeted for this purpose and fishers are generally not paid for the delivery. Shark cartilage pills became popular in the mid 1980s due to the erroneous belief that sharks do not get cancer and the pills are an effective cancer treatment (Musick and Bonfil 2005). The cartilage pills are produced by drying and pulverizing the shark cartilage and reforming into a pill. Cartilage pills contain chonrdroitin (chondrin derivative) and glucosamine sulfate; both compounds may have medical benefits for the treatment of arthritis and are marketed as such. Cartilage extract is another product that was used as a cancer treatment until recent medical studies debunked its use (Lu et al. 2010). Dogfish may also be used as tourist curiosities (e.g., dogfish in a jar), dissection in biology classes, aquarium specimens, or livers rendered into vitamins (Vannuccini 1999; Musick and Bonfil 2005); however, these uses comprise a very small part of the overall dogfish market.

## 4.9 Product Quality

The distribution chain for dogfish includes harvesters, processors, wholesale distributors, secondary processors, and retail. Maintaining quality from the harvesters to the final retail sale is critical. Careful handling of product from capture to consumption is important for all whitefish species; however, dogfish are particularly prone to spoilage due to high ureic content in the tissue (ammonia). Preventing spoilage and cross contamination requires maintaining the quality of dogfish throughout the entire distribution chain, from the point of capture to final consumer sale. Maintaining product quality requires developing, implementing, and enforcing quality standards throughout the market chain, particularly at the point of capture. The salmon industry has taken an end-to-end chain of custody approach for their target product by promoting handling procedures from harvest to sale. Dogfish would likely need a similar approach for firms not vertically integrated to insure high product quality from the point of capture to wholesale delivery.

Certain handling techniques are required at the point of capture and during processing to insure a high product quality. Exsanguination of dogfish followed by chilling is a method that greatly improves product quality. Although no dogfish specific exsanguination study is known, the method increases quality in other species such as Atlantic and Pacific cod, mackerel (*Scombridae*), and trout (*Oncorhynchus mykiss*) (Valdimarsson et al. 1984; Botta et al. 1986; Huss 1995). Bleeding likely reduces bacterial and enzymes that cause meat degradation and may also improve product appearance by reducing or eliminating blood spotting on the meat. The most important handling technique is to chill the dogfish below 35$^{o}$ degree Fahrenheit (1.7 $^{o}$ C) upon capture and limit trips to a maximum of 3 days if non-frozen dogfish is offloaded at a shoreside plant (Mercker[7]). However, it is noted that vessels fishing in Atlantic US waters and on short duration trips (i.e., day trips) may deliver whole ungutted dogfish to the processors. Large dogfish also pose a problem due to EU import regulations governing mercury concentrations; Alaskan fish, like dogfish from other US Pacific Ocean areas, can have high mercury loads, particularly for larger animals (Verbrugge 2007; Mercker[7]). In Alaska, mercury in dogfish is a concern because Alaskan dogfish tend to be larger than dogfish from other parts of the world (Gasper et al. in prep b; Tribuzio et al. 2010). Large dogfish may be mixed in with smaller fish such that the average mercury concentration of the shipment lot meets import standards.

Limited information is available on the variability of packaging and value added packaging. Backs are packaged into median, large, or jumbo packages. For medium sized backs, packages are either 5 kg or 12.7 kg in weight and the large or jumbo packages (cartons) weigh 12.7 kg. Flaps (bellies) are graded into medium, large, and trimmings and all are packaged in 15 kg cartons (Bella Coola[8]). Bella Coola Fisheries Ltd. also offers other products including eggs (candles) that are graded as large or small and packaged in 7 kg cartons, fins that are packaged in 10 kg cartons, and dried un-milled cartilage that is packaged in 318 kg totes. Crapo et al. (1993) provided a comprehensive overview of product recovery rates for dogfish. For the main products recovery rates (based on round weight) are as follows: 30% for backs; 5% for belly flaps; 4% for tails and fins; 75% for dressed headed; and 55% for dressed head off. For dogfish that are dressed with head on, the product recovery is 38% for backs; 7% for belly flaps; and 10% for fins.

## 4.10 Competitors

Multiple protein sources compete with Alaska dogfish products on an international market. Like most fish species, non-seafood sources of competition include beef, poultry, and pork. Alaskan dogfish also has competitors from other dogfish suppliers throughout the world including those from the US and Canada. *United States:* The primary sources of US supply occur on the Atlantic coast as well as smaller amounts of the west coast. There are at least two firms on the east coast selling both fresh and frozen product. On the west coast, the single firm selling dogfish (Arrowac Inc.) closed its dogfish plant in 2008 and it remains closed as of 2010 (Mercker[7]). Dogfish volume from the US Atlantic was in sharp decline during the early 2000s due severe quota limits designed to rebuild overfished stocks. Catch decreased from a high of 24,130 t in 1996 to 1,416 t in 2004 before a small increase

[8] Bella Coola. 2011. Bella Coola Fisheries Ltd. Product offering at http://www.belcofish.com/dog.html. [Accessed 30 May, 2011]. Delta, British Columbia.

to 4,000 t in 2008. Dogfish in the US Atlantic are no longer listed as "overfished" under the MSA, resulting sustainable harvest levels that will result in higher export volumes (Gasper et al. in prep b).

The reduction of marine whitefish supplies, particularly Atlantic cod, has increased the importance of Alaska whitefish products. Alaska has become an important supplier of Pacific cod, accounting for more than 94% of the US domestic harvest and one-fourth to one-third of the total world supply of Atlantic and Pacific cod (Knapp[9]). Product forms for cod are generally in fillet or headed and gutted, with the latter accounting for the largest market share. The re-export of Pacific cod to China where it is turned into skinless and boneless fillets likely explains the larger volume of H&G Pacific cod originating from Alaska (Knapp[9]).

In conclusion, market impact from increased Atlantic harvest is not clear due to the small dogfish market. On the one hand, market channels for dogfish from the Atlantic are well established and will compete with Alaska dogfish. On the other hand, dogfish markets are currently small and increased investment in marketing and product labeling may improve overall market conditions. Small harvest from the US coast likely will not be a significant competitor due to severe harvest restrictions associating with fishing areas and seasons, and legislation in California and Washington banning the possession of shark fins.

*Canada:* Canadian exports are generally minor; however, the British Columbia Hook-and-Line Industry Association is currently seeking MSC certification that could

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[9] Knapp, G. 2006. Selected market information for Pacific cod. Paper prepared for the North Pacific Fisheries Management Council. Anchorage, AK.

improve dogfish marketing. Most dogfish (approximately 60%) entering the UK market directly from Canada originates from British Columbia, but this number may be higher if dogfish is re-exported from other EU countries to the UK. Of all the dogfish exported by Canada, 80% originates from British Columbia. Between 2006 and 2008, Canadian export volume to the UK has been approximately 400 t for frozen product and 100 t for fresh product, with some of this volume originating from US waters (Gasper et al. in prep b). British Columbia has certain advantages over Alaska in that many parts of Alaska are remote and shipping can be expensive, particularly for fresh products.

*Other parts of the world:* Harvests from Europe, New Zealand, and South America are potential sources of future supply. European harvest is likely to remain depressed in the near future due to the poor condition of stocks; however, New Zealand is already a significant supplier to Asia and occasionally some EU countries. Dogfish also occur in waters off Chile and Argentina, but stock status, capture statistics, and trade information are lacking. Trade statistics for the EU and North America show low volume of dogfish from South America, but dogfish could be entering the EU through third parties not reporting trade information. Further, South American exports to Asia are unknown.

### 4.11 Current Marketing Situation

Overall, Alaska is in a good position to enter the international dogfish market (both Asia and Europe) due to pre-existing harvesting, processing, and transportation infrastructure and a relatively high dogfish abundance. However, there are significant barriers to overcome associated with the additional transportation costs to get the fish to market and motivation for fishermen to harvest dogfish when more valuable species are available. A detailed summary of these issues is provided in the strength, weaknesses, opportunity, and threats (SWOT) analysis summarized below:

4.11.1 Strengths

1) *Harvesters in Alaska have the technology, capacity, and knowledge to properly produce high quality fish products.* This includes infrastructure for ice distribution; onboard freezing or chilling equipment; landing ports with processing capacity, cold storage, and access to transportation facilities. The seafood industry is a significant contributor to the Alaska economy. Alaska led all states in landings and ex-vessel value, with 1.85 million t worth an estimated 1.3 billion USD in 2009 (Haitt et al. 2010). The industry is very sophisticated in logistics and transportation associated with delivery of product to market. Further, development of a dogfish fishery may be welcomed by harvesters looking for "open access" types of fishing opportunities that have been constrained by fishery rationalization.
2) *Alaska has a respected brand name that helps sell Alaskan products.* People tend to believe that Alaska seafood, even if not MSC certified, is sustainable and healthy (Haitt et al. 2010). Alaskan tourism marketing also likely contributes to this belief.
3) *Dogfish are abundant in Alaskan waters and are sustainably managed as required under the MSA.* This is a strong advantage both for consumer

perception and stability in volume. Dogfish are managed conservatively to account for uncertainty and this management approach taken by the North Pacific Fishery Management Council, State of Alaska Board of Fisheries, National Marine Fisheries Service, and the State of Alaska has insured no groundfish stocks are overfished. Other parts of the world have experienced poor management that has resulted in inadequate supplies and consumer perception. This creates instability that erodes market share, reduces marketing investment, and changes product position.

4) *There is political and legal support (e.g., National Standard 9 of the MSA) for increased utilization of species that would otherwise not enter commerce and be discarded at sea.* The North Pacific Fishery Management Council has supported numerous industry-related activities to reduce bycatch and increase utilization.

4.11.2 Weaknesses

1) *Costs of transporting product is high in Alaska.* Markets are distant from Alaska in comparison with the US mainland or Canada. This creates added costs that Alaska processors and wholesale firms must consider when determining market feasibility, particularly for fresh products that require timely delivery.

2) *Processing of dogfish is labor intensive, requiring trained processing labor to grade, process, and pack dogfish with the highest quality (Mercker[7],*

*Waweru[10]).* Dogfish processing is labor intensive and cannot be done using available machinery (Mercker[7]). Alaska has processing capacity to handle dogfish, but fishermen and processing workers will need training to process the species. Processing methods for dogfish are dissimilar to target species currently processed in that they involve different cuts for back, bellies, and fins, and skinning process. Shipping whole gutted dogfish for re-processing may be an option to reduce training needs in Alaska.

3) *Dogfish has a small share of the whitefish market and cannot be a high volume fishery.* A high volume fishery is not feasible for dogfish because their biology prohibits high harvest volumes for the stock to remain in a sustainable status. One marketing approach is to offer a very high quality, but low volume product that fits niche markets.

4) *Dogfish have a perception problem among consumers.* The market name "spiny dogfish" does not conjure up images of fish that people want to eat despite a light, tasty flavor. Further, dogfish are a shark species that has a poor reputation in the EU for two primary reasons: 1) negative environmental connotations due to efforts by environmental groups to discourage consumption of shark meat; and 2) health concerns due to heavy metals that bioaccumulate in the animal's tissue. Careful consideration will need to be given to the market name; currently FDA guidance provides four market names (FDA 2010): Spring dogfish, spiked dogfish, grayfish, spur dog, piked dogfish. Renaming has occurred in other species such as the change from

[10] Waweru, M. 2009. Yakuat Seafoods. Yakutat, Alaska. Personal commun.

Pacific hake (*Merluccious productus*) to Pacific whiting. However, stakeholders must exercise caution to avoid fraudulent naming conventions.

5) *Dogfish are a whitefish species with wholesale prices on par with higher volume species such as cod, haddock, and pollock.* The ex-vessel value for dogfish is generally between 0.07 USD/lb (0.16 USD/kg) and 0.25 USD/lb (0.55 USD/kg), which is lower than Alaskan groundfish and salmon (Table 7). However, wholesale prices overlap high volume groundfish species and range from 2.00 USD/ lb (4.44 USD/kg) to 4.00 USD/lb (8.88 USD/kg). The low reproductive potential for dogfish precludes the species from being a high-volume fishery. To compensate for low marginal profits due to low volume, marketing should maximize value adding (e.g., packaging, providing a fin product, and maintaining high product quality). Increased processing efficiency may reduce costs and in turn increase ex-vessel prices, but current processing methods are labor intensive and investment would be required to establish methods to reduce labor costs.

6) *Alaska does not have an established market channel for dogfish.* Alaska processors will need to develop market intelligence to identify opportunity, monitor competitor moves, define market penetration strategies, and build relationships with seafood buyers and wholesale distributors in Europe and Asia.

7) *Shipping to the EU requires meeting EU seafood standards and obtaining necessary permits.* The cost associated with obtaining these permits is

unknown. Mercury regulations will require additional monitoring of exports to the EU to ensure compliance.

4.11.3 Opportunities

1) *Reduced discard and meeting the goals of National Standard 9 in the MSA.* Dogfish are current discarded with unknown discard mortality. Establishing market channels for dogfish would likely increase the utilization, which has occurred with other groundfish species such as arrowtooth flounder (*Atheresthes stomias)* and skates.
2) *Longline vessels with onboard plate freezers may be able to accommodate dogfish during "shoulder seasons."* These vessels have the potential to produce a very high quality frozen at-sea dogfish product, which would target specific market segments in the EU (e.g., restaurants).
3) *Utilizing the Alaska "brand" to sell dogfish as a sustainable source of high quality seafood.* Seafood branding has been used to maintain market share and establish in emerging markets. The Alaska Seafood Marketing Institute is one such program that provides seafood marketing resources, seafood traceability standards, and third-party certification based on FAO criteria for responsible management. Successful branding campaigns in Alaska include Copper River Red salmon and Wild Alaskan Halibut among others.
4) *MSC certification for Alaska dogfish would likely increase marketability of Alaskan dogfish.* In addition to Alaska specific branding and certification, MSC labeling is another option to differentiate dogfish from other sources and

whitefish species. Both the Alaskan pollock and freezer-longline Pacific cod fisheries leveraged MSC to introduce products into the EU, a market they previously had difficulty penetrating (MSC 2010b). The Alaskan sablefish and halibut IFQ fisheries are also both certified and report political benefits (MSC 2010b).

5) *A directed dogfish fishery would benefit fishers due to the revenue generated for dogfish as well as the MRA from valuable groundfish species.* A downside is that allocation conflicts may arise if retention of fully allocated species is high.

6) *Increased North American supply: dogfish supplies from British Columbia and Atlantic coast US states will likely become more prominent in the near future.* Currently, British Columbia and the Atlantic US are seeking MSC certification for spiny dogfish, which may allow them to address consumer concerns about sustainability and more effectively market dogfish. Alaska can take advantage of this market channel and, between the three major sources of dogfish, stabilize volume and provide reliable supply for consumers. This is critical for building maintaining market share for dogfish products.

4.11.4 Threats

1) *Downward pressures on price.* Expanded dogfish supply from US, British Columbia, and other parts of the world would place downward pressure on prices and could potentially lower product quality. Flooding the market with

product (particularly poor product) will offset the benefits described in opportunity 6.

2) *Value and supply of sablefish, halibut, and Pacific cod in Alaska:* Fishermen and processors targeting valuable species are less likely to use hold or freezer capacity for dogfish unless harvesting of dogfish provides MRA opportunity for high valued species or dogfish ex-vessel prices increase. Skate harvest increased when ex-vessel prices approached those of Pacific cod; however, the price offering that would encourage dogfish fishing is unknown and would need to be negotiated between processors and harvesters.

3) *Establishing an Alaskan dogfish market in the EU is going to require marketing investment and a robust quality assurance.* The ability of processors and wholesale firms to make this investment may not be realistic for the species due to high processing and handling costs along with relatively low ex-vessel value.

4) *Increasing fuel and operating costs may make the targeting of dogfish uneconomical.* The distribution of fishing effort has been influenced by high fuel prices in the past. For example, a combination of low ex-vessel flatfish prices and high fuel costs caused some trawl vessels in Kodiak to not fish in 2009 (Josh Keaton[3]). Dogfish ex-vessel value is low and therefore unless a valuable species can be caught incidentally to dogfish, targeting and retention of dogfish is unlikely when fuel costs are high.

5) *Directed fishing for dogfish may increase the use of valuable incidental halibut allocation.* In most non-IFQ fisheries halibut must be discarded at sea and those discards accrue toward sector limits that once reached can result in fishery closure. Targeting of dogfish may result in an increase in incidental halibut catch and may restrain non-dogfish fisheries. Further study is needed to determine the extent of this issue.
6) *Directed fishing may increase the harvest of female dogfish due to their large size.* Directed dogfish fisheries throughout the world have focused on large female dogfish because, due to their size, they have a higher market value then their smaller male counterparts. Even without such targeting, fishing generally disproportionately depletes the older, larger individuals in a population, resulting in a truncated age/size structure. The harvesting of large females impacts the dogfish stock because they are the most fecund and most important for future recruitment. Future stock assessments may require data collected by at-sea fishery observers to characterize the composition of fishery catch and discard to account for female mortality.

## 4.12 Conclusion

Alaska fishers are unlikely to retain a substantial amount of dogfish based on historical ex-vessel prices that range from 0.07 USD/lb to 0.30 USD/lb. Sporadic retention may occur in areas with high dogfish abundance and relatively low harvesting costs (e.g., Yakutat set net fishery). Marketing and processing investment will be required to expand the Alaskan market for dogfish into Asia and Europe.

Marketing efforts should focus on the benefits and opportunities for consumers that Alaskan dogfish provide, including a stable and sustainable supply, high product quality, and leverage consumer experience based on other Alaskan products. The fresh and frozen markets for backs, bellies, and fins are viable marketing targets, but emphasis must be placed on quality rather than quantity; a sustainable Alaskan dogfish fishery will never be a high volume fishery. Marketing efforts may also leverage efforts in Canada and elsewhere in the US to enhance the market image of dogfish and increase its competitiveness with other whitefish species.

A directed fishery rather than a bycatch-only fishery would produce the highest volume and provide the most secure long-term market position for Alaskan dogfish. Smaller volumes of dogfish could be harvested in an incidental fishery, but this would require a substantial increase in ex-vessel price and may not provide long-term market stability. A directed fishery provides the added incentive to harvest dogfish in that fishers are able to also harvest valuable MRA species. Harvesting valuable groundfish species also offset low ex-vessel values for dogfish. The opening of a directed fishery would require regulatory action from both State and federal regulatory advisory bodies and their respective management agencies. Historically, Alaskan management bodies are reluctant to allow directed fishing on data-poor species vulnerable to overfishing. Dogfish are a data-poor species that will require improvements to the stock assessment before a directed fishery is allowed in either State or federal waters. The closure of directed shark fishing in all waters (unless specially permitted) reflects precautionary management of data-poor stocks.

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Table 4.1 Catch and value of dogfish harvest in southeast Alaska for liver oil as reported by DOI (1958). Data are total catch in pounds (lbs), total liver weight (lbs), nominal value (Nom), gallons (G) of oil, and value in 2010 dollars Nominal values were adjusted for inflation using the Consumer Price Index. NR indicates no shark data is reported, which likely means no significant amounts of product was produced between 1927-1940 and 1955-1958.

| Year | Total (1000s lb) | Nom. (USD) | 2010 (USD/ lb) | Liver (1000s lb) | Nom. (USD) | 2010 (USD) | Oil (1000 G) | Nom. (USD) | 2010 (USD/G) |
|---|---|---|---|---|---|---|---|---|---|
| 1940 | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| 1941 | 482.31 | 17,172 | 0.53 | 72.4 | 17,172 | 3.54 | -- | -- | -- |
| 1942 | 1,649.1 | 33,244 | 0.27 | 5.5 | 1,085 | 2.62 | 29.5 | 41,348 | 18.67 |
| 1943 | 1,198.2 | 65,915 | 0.70 | 314.3 | 72,392 | 2.92 | -- | -- | -- |
| 1944 | 3,540.2 | 128,382 | 0.45 | 424.8 | 109,584 | 3.18 | -- | -- | -- |
| 1945 | 2,553.2 | 70,543 | 0.33 | 124.2 | 26,123 | 2.53 | -- | -- | -- |
| 1946 | 6,149.6 | 58,914 | 0.11 | 265.2 | 151,975 | 6.44 | 17.2 | 120,141 | 78.65 |
| 1947 | 1,711.1 | 22,104 | 0.13 | 149.0 | 57,938 | 3.81 | 7.8 | 35,834 | 45.19 |
| 1948 | 1,948.1 | 35,066 | 0.16 | 162.8 | 80,322 | 4.44 | 14.2 | 63,884 | 40.54 |
| 1949 | 1,289.1 | 23,203 | 0.17 | 143.6 | 40,889 | 2.61 | 2.8 | 5,468 | 18.24 |
| 1950 | 16.9 | 101 | 0.05 | 2.0 | 117 | 0.52 | -- | -- | -- |
| 1951 | 11.0 | 110 | 0.08 | 1.3 | 155 | 0.99 | -- | -- | -- |
| 1952 | 3.6 | 53 | 0.12 | 0.4 | 170 | 3.27 | -- | -- | -- |
| 1953 | 2.5 | 131 | 0.44 | 0.3 | 131 | 3.65 | -- | -- | -- |
| 1954 | 2.8 | 141 | 0.41 | 0.3 | 141 | 3.43 | -- | -- | -- |
| 1955 | NR | NR | NR | NR | NR | NR | NR | NR | NR |

Table 4.2 Tons of dogfish catch (retained and discarded) in the Federal groundfish fisheries. Data provided by the National Marine Fisheries Service, Alaska Region.

| | | Reporting Area | | | | | |
|---|---|---|---|---|---|---|---|
| Gear | Year | 610 | 620 | 630 | 640 | 650 | Total |
| Hook and Line | 2003 | 6 | 18 | 5 | 37 | 15 | 81 |
| | 2004 | 16 | 8 | 61 | 28 | 35 | 148 |
| | 2005 | 11 | 21 | 203 | 87 | 47 | 369 |
| | 2006 | 59 | 131 | 392 | 194 | 207 | 983 |
| | 2007 | 49 | 76 | 225 | 29 | 188 | 567 |
| | 2008 | 11 | 9 | 251 | 24 | 49 | 343 |
| | 2009 | 68 | 276 | 151 | 66 | 218 | 779 |
| | 2010 | 50 | 43 | 36 | 11 | 63 | 203 |
| Other Fixed Gear | 2003 | 0 | <1 | 2 | 0 | 0 | 2 |
| | 2004 | <1 | <1 | <1 | 0 | 0 | <1 |
| | 2005 | 0 | <1 | 5 | 0 | 0 | 6 |
| | 2006 | <1 | <1 | 4 | 0 | 0 | 4 |
| | 2007 | 1 | 2 | 6 | 0 | 0 | 10 |
| | 2008 | 0 | <1 | <1 | 0 | 0 | <1 |
| | 2009 | <1 | <1 | <1 | 0 | 0 | 1 |
| | 2010 | <1 | <1 | <1 | 0 | 0 | <1 |
| Trawl | 2003 | 3 | 43 | 227 | 2 | 0 | 274 |
| | 2004 | 3 | 3 | 28 | <1 | 0 | 35 |
| | 2005 | <1 | 11 | 58 | <1 | 0 | 69 |
| | 2006 | <1 | 17 | 160 | 4 | 0 | 182 |
| | 2007 | 4 | 23 | 223 | 4 | 0 | 255 |
| | 2008 | 1 | 62 | 123 | 3 | 0 | 189 |
| | 2009 | <1 | 44 | 186 | 17 | 0 | 247 |
| | 2010 | 3 | 25 | 165 | 1 | 0 | 194 |
| All Gears | 2003 | 9 | 61 | 234 | 38 | 15 | 357 |
| | 2004 | 20 | 12 | 90 | 28 | 35 | 184 |
| | 2005 | 11 | 32 | 266 | 87 | 47 | 443 |
| | 2006 | 60 | 148 | 556 | 198 | 207 | 1169 |
| | 2007 | 55 | 101 | 455 | 33 | 188 | 831 |
| | 2008 | 12 | 71 | 374 | 27 | 49 | 533 |
| | 2009 | 69 | 320 | 337 | 83 | 218 | 1027 |
| | 2010 | 53 | 68 | 202 | 12 | 63 | 398 |

Table 4.3 Summary of incidental retainable percentages for Federal and State groundfish (GF), State salmon fisheries, and the federal IFQ halibut fishery where dogfish catch may occur. Note this table does not include State drift gillnet, non-Yakutat set gillnet, or seine. Summary is based on 2010 regulations and State Emergency Orders. Note that SE indicates Southeastern Alaska, NSEI and SSEI area Northern and Southern Southeastern Inside waters, respectively.

| | Type of Retention Limit | | | |
|---|---|---|---|---|
| | Dogfish (%) | Aggregate (%) | Federal Other Species (%) | Directed |
| Federal GF | -- | -- | 20 | -- |
| SE DSR Longline | 35 | -- | -- | -- |
| SE DSR Jig | 20 | -- | -- | -- |
| NSEI Sablefish | 35 | -- | -- | -- |
| SSEI Sablefish Longline | 35 | -- | -- | -- |
| SSEI Sablefish Pot | 20 | -- | -- | -- |
| Pacific Cod SE Longline | 35 | -- | -- | -- |
| Pacific Cod SE other gear | 20 | -- | -- | -- |
| Halibut IFQ Longline | 35 (SE State waters only) | 20 (Non-SE State waters) | 20 | -- |
| Halibut IFQ Jig | 20 | 20 | -- | -- |
| SE Lingcod and Black Rockfish | 20 | -- | -- | -- |
| SE Salmon Troll (hand and power) | 35 | -- | -- | -- |
| Yakutat Set Net | -- | -- | -- | Incidental to Salmon |
| Other State GF | -- | 20 | 20 (parallel) | -- |

Table 4.4 Estimated potential total and median catch per trip by port of landing for Federal hook-and-line and fisheries. Note that the Southeast port includes all ports in Federal reporting areas 650 and 640. The Prince William Sound ports include Valdez, Cordova, Seward, and Whittier. Note that total are higher than the sum of ports due to the exclusion of landings made out of Alaska.

| Port Area | 2008 | | 2009 | | 2010 | |
|---|---|---|---|---|---|---|
| | Sum (t) | Median Per Trip (t) | Sum (t) | Median Per Trip (t) | Sum (t) | Median Per Trip (t) |
| Southeast | 1,667 | 0.52 | 1,394 | 0.57 | 1,301 | 0.51 |
| Kodiak | 2,104 | 0.78 | 2,042 | 1.12 | 2,014 | 1.08 |
| Prince William Sound | 400 | 1.79 | 436 | 1.55 | 425 | 1.41 |
| Western | 906 | 0.76 | 819 | 0.72 | 859 | 0.67 |
| Cook Inlet | 2,404 | 1.48 | 2,574 | 1.66 | 2,337 | 1.61 |
| Total | 7,481 | -- | 7,283 | -- | 6,993 | -- |

Table 4.5 Tier 5 OFL and ABC specifications for spiny dogfish. Because of the biennial trawl survey schedule, biomass estimates are based on 3 year average, which results in a 1-year lag between the harvest specification calculation and last year in the biomass average (e.g., 2003, 2005, and 2007 survey used for the 2008 harvest specification).

| | 2008 | 2009 | 2010 |
|---|---|---|---|
| Biomass Est. | 102,878 | 79,256 | 79,256 |
| OFL | 9,979 | 7,688 | 7,688 |
| ABC | 7,484 | 5,766 | 5,766 |

Table 4.6 Summary of the estimated potential Other Species Complex MRA that could be harvested between 2008 and 2010 for longline fisheries in Federal water. Values are in metric tons per trip within a vessel category. The table describes three regions: the eastern GOA (EGOA), central GOA (CGOA), and western GOA (WGOA). Note this table does not include State fisheries and assumes a Federal MRA for halibut IFQ fisheries occurring in State waters.

| | | Vessel Length Overall Category (feet) | | | |
|---|---|---|---|---|---|
| | | 15-29 | 30-59 | 60-89 | >89 |
| EGOA | Mean | 0.09 | 1.16 | 2.46 | NA |
| | Median | 0.07 | 0.79 | 2.21 | NA |
| | SD | 0.08 | 1.17 | 1.89 | NA |
| CGOA | Mean | 0.10 | 1.50 | 3.08 | 3.09 |
| | Median | 0.07 | 1.12 | 2.44 | 3.10 |
| | SD | 0.28 | 1.45 | 1.95 | 1.79 |
| WGOA | Mean | 0.25 | 1.12 | 2.24 | 2.19 |
| | Median | 0.16 | 0.65 | 1.36 | 2.26 |
| | SD | 0.21 | 1.29 | 2.27 | 1.76 |

Table 4.7 Proportion of the MRA by area of capture and port of landing for "other" species in Federal hook-and-line fisheries for the year 2008 through 2010.

| | NMFS Reporting Area | | | | | |
|---|---|---|---|---|---|---|
| | 610 | 620 | 630 | 640 | 650 | Total Weight (t) |
| Southeast | <0.01 | <0.01 | 0.02 | 0.25 | 0.73 | 4,361 |
| Kodiak | 0.03 | 0.29 | 0.68 | 0.01 | <0.01 | 6,159 |
| Prince William Sound | <0.01 | 0.01 | 0.38 | 0.61 | <0.01 | 1,261 |
| Western | 0.87 | 0.13 | 0.01 | -- | -- | 2,584 |
| Cook Inlet | 0.04 | 0.17 | 0.70 | 0.09 | <0.01 | 7,315 |
| Other | 0.35 | 0.43 | 0.20 | -- | 0.01 | 75 |

Table 4.8 Comparison of Alaskan product values by species for the years 2007-2009.

| | Ex-Vessel (USD/lb) | H&G (USD/lb) | Fillets/Other Product[3] (USD/lb) |
|---|---|---|---|
| Sablefish[1] | 2.78-3.42 | 4.86-5.95 | -- |
| Halibut[2] | 2.97-4.13 | -- | -- |
| Pacific Cod[1] | 0.30-0.56 | 0.91-1.69 | 2.62-3.99 |
| Rockfish[1] | 0.69-0.72 | 0.87-0.96 | 1.76-2.17 |
| Dogfish | 0.07-0.30 | 0.07-0.40 | 1.00-4.00 |
| Salmon Troll Chinook | 3.60-7.30 | -- | -- |
| Salmon Troll Coho[3] | 1.33-2.70 | -- | -- |

[1] Ex-vessel values from Haitt et al. (2009) for longline gear: 2007-2009.
[2] Ex-vessel values from NMFS Restricted Access Division annual IFQ fee percentage notice for the halibut IFQ program 2007-2009.
[3] Salmon troll values obtained from the State of Alaska Commercial Fishery Entry Commission (Farrington[11]). Note that shoreside troll salmon are gutted prior to delivery and some may be frozen at-sea.

[11] Farrington, C. 2011. State of Alaska Commercial Fisheries Entry Commission. Juneau, Alaska. Personal commun.

## 4.16 Figures

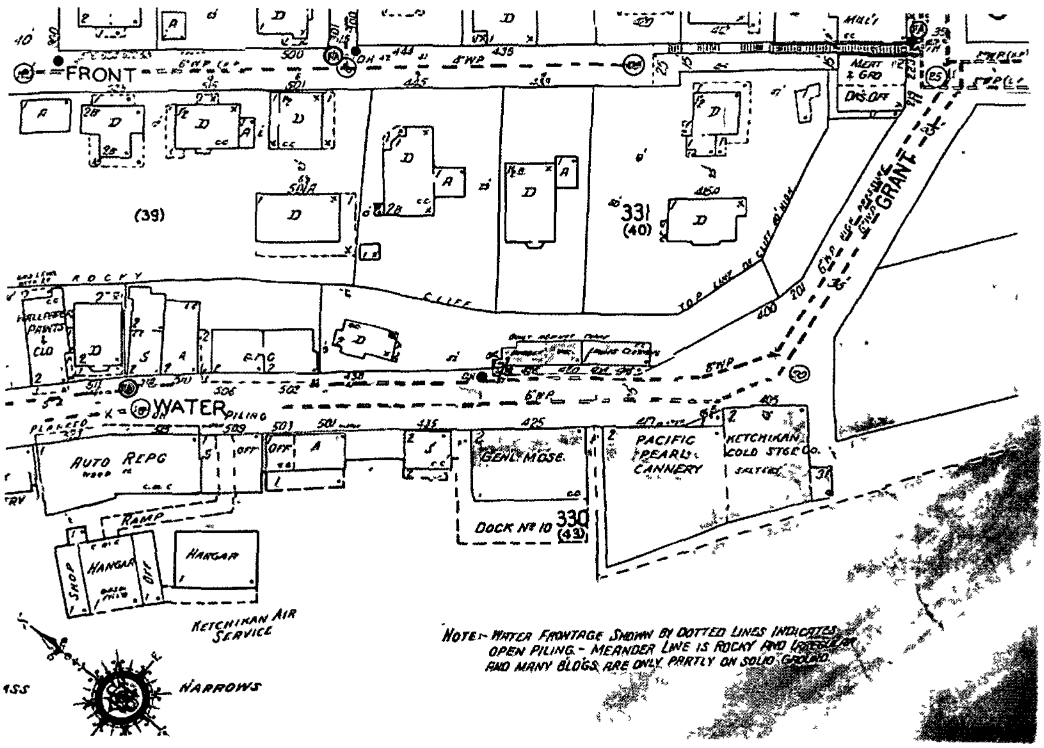


Figure 4.1. Map of Ketchikan harbor circa 1950s showing the location of the general area where Alaska Fish Oil Extractors (near Ketchikan Cold Storage) was located. Photo courtesy of the City of Ketchikan Museums.

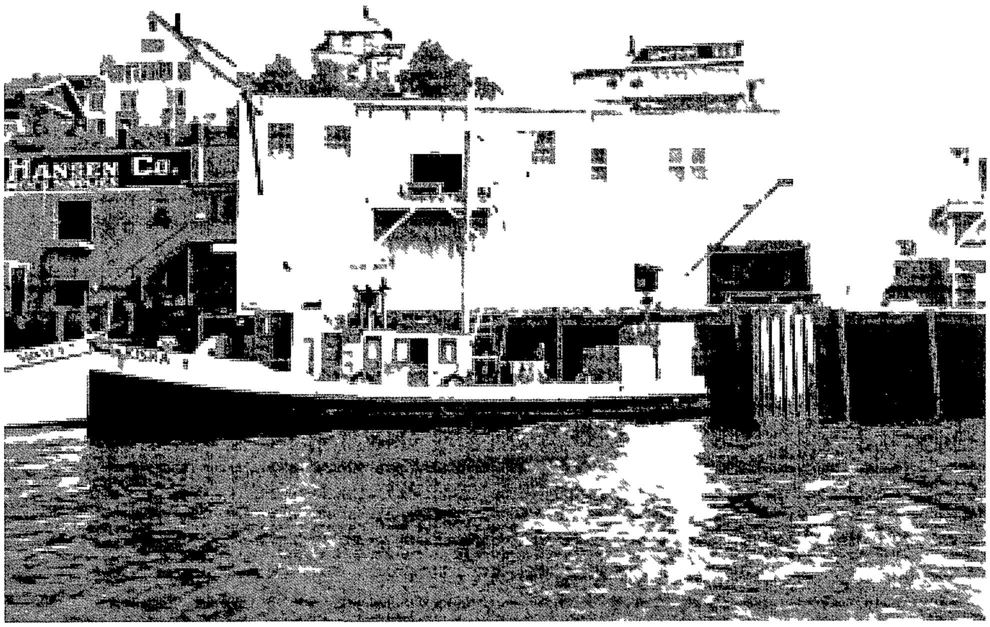


Figure 4.2 Photo of vessel offloading to Alaska Fish Oil Extractors. Photo courtesy of the City of Ketchikan Museums.

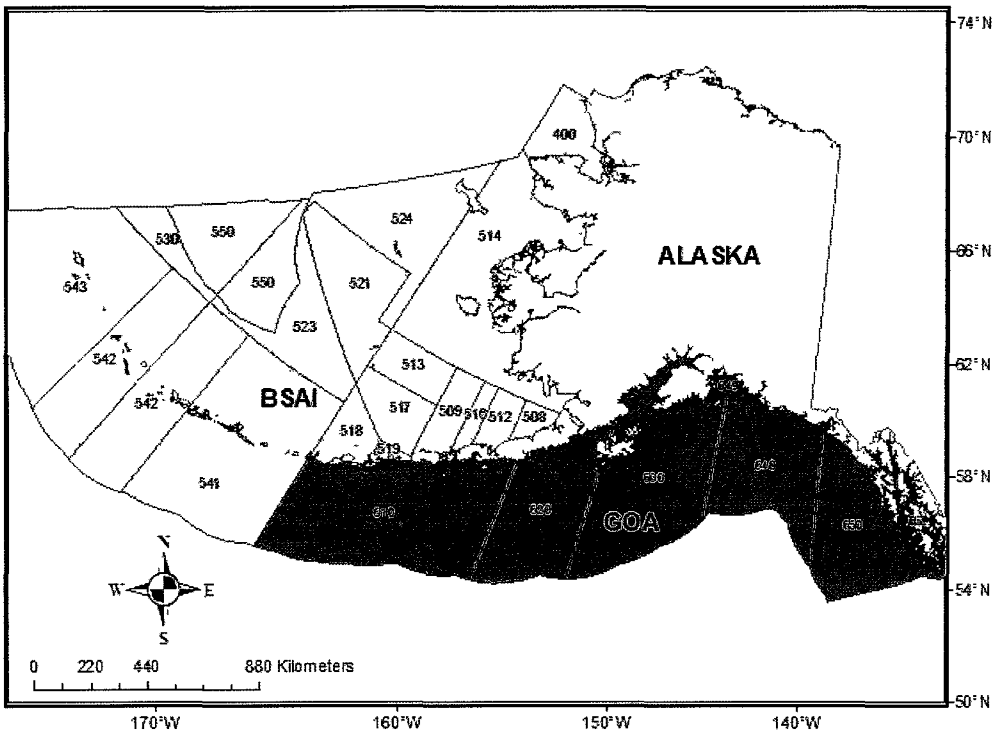


Figure 4.3. Gulf of Alaska (GOA) and Bearing Sea/Aleutian Islands (BSAI) federal reporting areas. Note that the Central GOA (CGOA) includes areas 620 and 630, the Western GOA (WGOA) is area 610, and the Eastern GOA (EGOA) comprises areas 640, 649, 650, and 659. Data from the National Marine Fisheries Service, Alaska Regional Office: May 1, 2011.

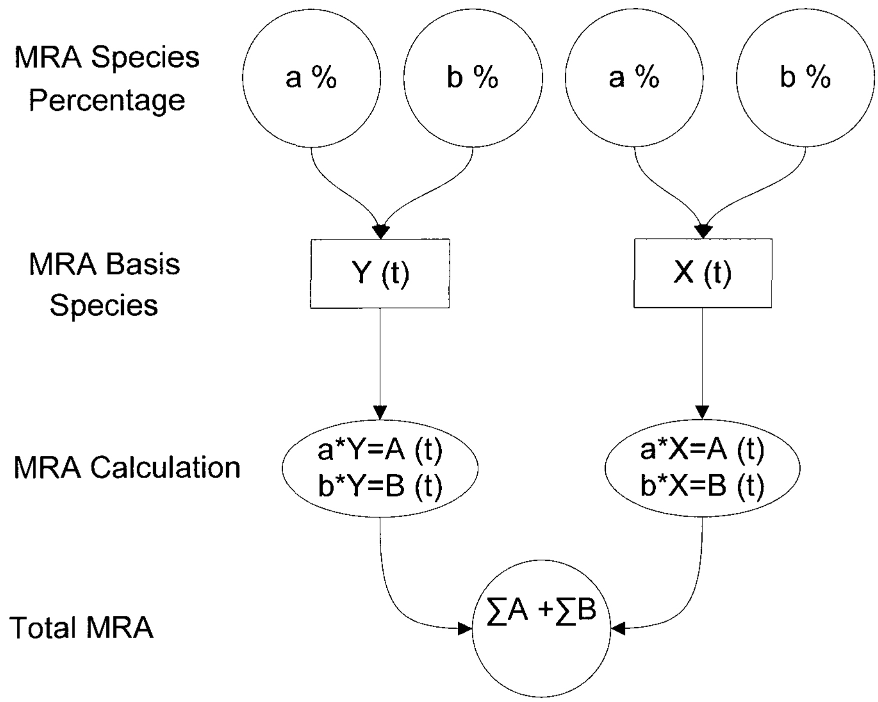


Figure 4.4. Example of MRA calculation method for two basis species (X and Y) and two MRA species (A and B).

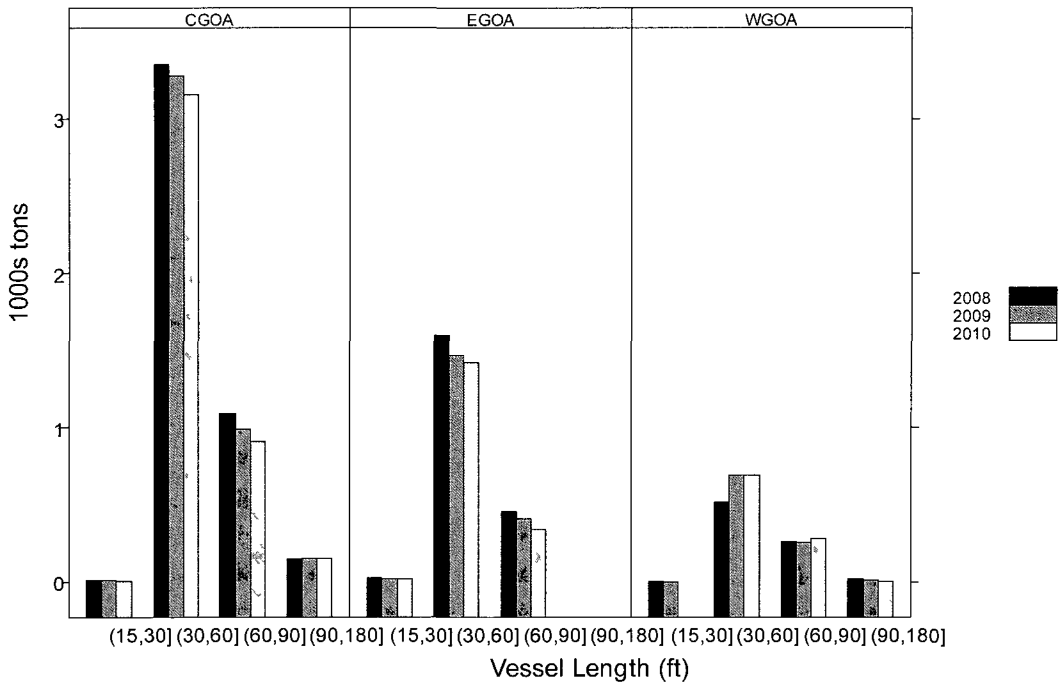


Figure 4.5. Estimated MRA amount for other species by vessel size and GOA region.

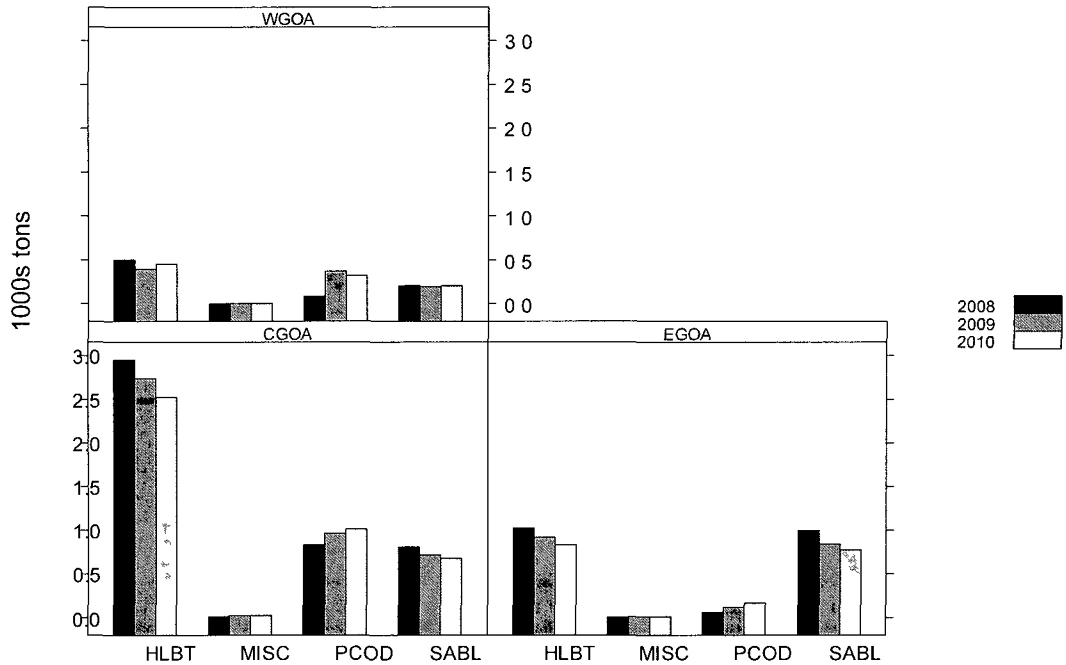


Figure 4.6. Volume of Other Species Complex MRA by target fishery and reporting area. Note that WGOA is reporting area 610, EGOA consists of reporting areas 640 and 650, and the CGOA consists of reporting areas 620 and 630.

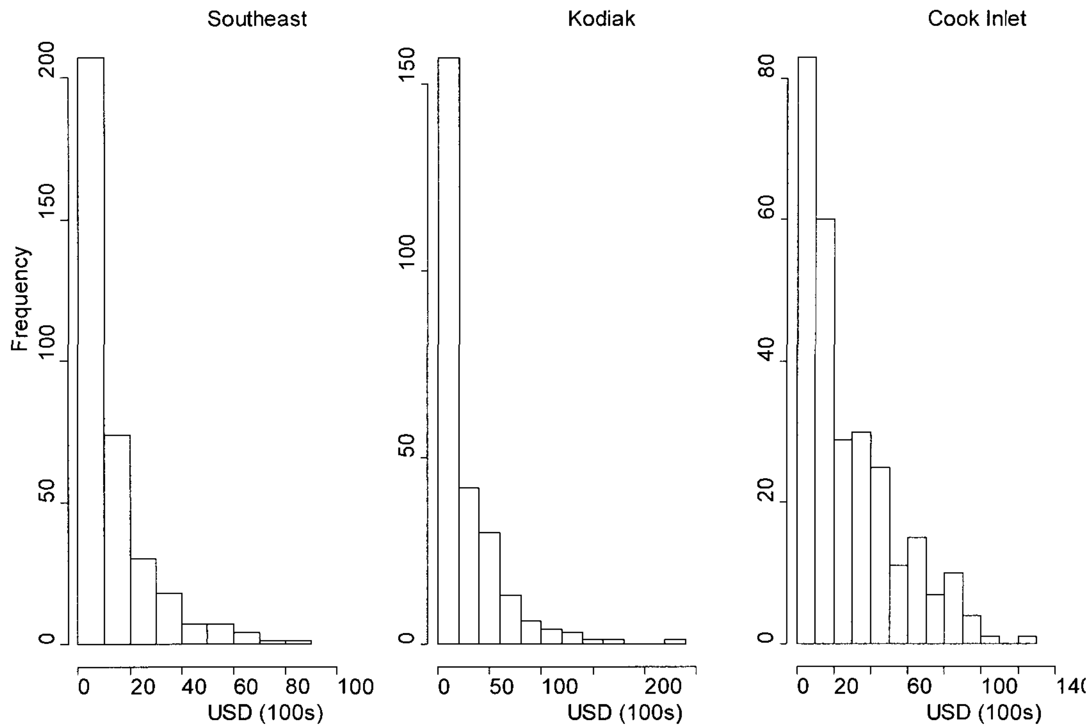


Figure 4.7. Distribution of total projected annual revenue for vessels retaining all Other Species Complex MRA as dogfish and an ex-vessel value of $0.15. The frequency histograms are grouped by port region where dogfish abundance is highest.

# Chapter 5 Conclusion

The results of this study provide an overview of the international market for dogfish and advance the knowledge about market structure, sustainability, and fishery development in Alaska. Together the three chapters illustrate the need for clear eco-labeling to differentiate sustainable sources of dogfish and stabilize or increase market share. Without differentiation, consumers have no method of differentiating products, which will discourage consumption in markets with eco-conscious consumers and obfuscate consumption choices in markets less impacted by eco-conscious behavior.

Investment by fishers in a dogfish fishery in Alaska will require considering product differentiation strategies on an international scale and educating consumers about Alaskan products. One approach would be to carefully choose an eco-label and environmentally positive brand that would highlight Alaska's history of sustainable management, existing seafood and fishery management infrastructure, high product quality, and historically stable supply due to a healthy dogfish population. However, leveraging this advantage will require regulatory changes that allow a directed fishery in waters off Alaska. Without this change, current low market value provides poor incentives to harvest dogfish. These incentives may change as other world suppliers (e.g., Canada and US) invest in markets, leading to increased demand and price increases. Regardless, management of a dogfish fishery must be cautious and improvements to the current Gulf of Alaska stock assessment model is needed to reduce uncertainly in setting annual catch limits.

Chapters 2 and 4 demonstrated that Alaska dogfish fisheries are most likely to develop in the eastern and central Gulf of Alaska given the distribution of fishing effort and dogfish density. The analysis focused on the longline fishery in this area, while recognizing that a trawl fishery is feasible if product quality is maintained. The world market structure described in Chapter 3 is useful for matching product quality requirements and economic efficiencies associated with gear. For example, very high quality and low volume dogfish products (e.g., fresh backs) require special handling that is typical of a longline vessel, while trawl fisheries may efficiently harvest products with less stringent handling requirements, such as frozen bellies or fins. Moreover, catcher processors (trawl or longline) may have a unique advantage in that they are able to freeze product at-sea, which may further differentiate Alaskan products on an international market.

Finally, this study has broad implications on the sustainable development of international fisheries. The results could be applied to develop Alaska dogfish fisheries as well as guide marketing strategy in the EU and Asia. Recent efforts by Canada (Pacific coast) and the US (Atlantic coast) to eco-label dogfish and invest in market development will likely have a positive influence on marketing opportunities for Alaska product. An important area of future research is to investigate consumer attitudes towards dogfish and eco-labels in the EU. This would better guide market strategy and investment. Further, significant opportunity likely exists in Asia, but information is largely unavailable on consumption patterns or inter-Asian trade for dogfish. Research describing these aspects of the Asian market would guide investment and help determine whether eco-labels would be effective.