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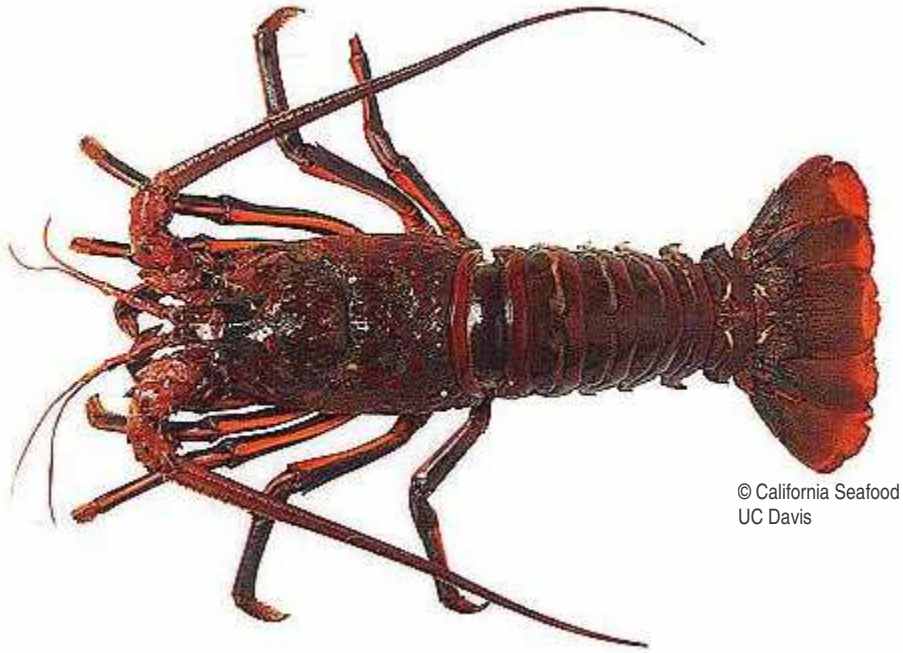
Assessment of the California Spiny Lobster *Panulirus interruptus* Recreational Fishery in the Santa Barbara Region



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A Group Project submitted in partial satisfaction of the requirements for the degree of
Master's of Environmental Science and Management
for the
Donald Bren School of Environmental Science and Management

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April 2006

ABSTRACT

Rates of harvest from open access recreational fisheries are difficult to quantify due to the combination of diffuse participation, variance in local-scale regulation, and uncertainty in estimates of fishing effort. Recent work estimates recreational harvest accounts for as much as 64% of total landings for some fisheries. Conservative estimates place worldwide recreational landings at approximately 10% of total fish landed when large industrial fisheries (i.e. Pacific sardine) are excluded. The California spiny lobster, *Panulirus interruptus*, is the subject of lucrative commercial and recreational fisheries in southern California. In 2004, the commercial fishery for spiny lobster landed 928,302 pounds at a value of $6,629,297. Ports in the Santa Barbara region, the northern most sector of the fishery, landed 396,350 pounds at a value of $2,935,470, approximately 43% of the total lobster CA fishery in 2004. The total biomass of lobster harvested each year is unknown because little quantitative data exists regarding recreational catch. Quantitative information about recreational harvests is essential for effective fishery management. A greater understanding of the dynamic processes that influence landings, the spatial and socio-economic distribution of effort, and future trends in catch and fishing technology will provide management agencies with information to manage lobster on ecosystem basis. Our study seeks to create replicable methods for defining recreational fishery drivers and quantifying harvest rates through survey sampling and analysis. In addition, our results indicate that the fishery supports a lobster stamp program that would enable the California Department of Fish and Game to monitor recreational harvests on an annual basis.

Assessment of the California Spiny Lobster, *Panulirus interruptus,* Recreational Fishery in the Santa Barbara Region

As authors of this Group Project we are proud to archive it on the Bren School's website such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Donald Bren School of Environmental Science and Management

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The Group Project, required by all students in the Master's of Environmental Science and Management (MESM) program, is a three quarter activity in which small groups of students conduct focused, multidisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. The final Group Project report is authored by MESM students and has been reviewed and approved by:

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April 2006

ACKNOWLEDGEMENTS

This project was made possible by the California Department of Fish and Game, the Channel Islands National Marine Sanctuary, the California Sea Grant Extension program, the Donald Bren School of Environmental Science and Management at the University of California, Santa Barbara, and the California Spiny Lobster.

We would especially like to thank Hunter Lenihan, whose guidance and leadership were integral throughout the project process, and whose unwavering support gave us the confidence and conviction to complete this investigation.

We would also like to thank our clients: Kristine Barsky, of the California Department of Fish and Game, Carrie Culver, of the California Sea Grant Extension Office, Sean Hastings and Chris LaFranchi, of the Channel Islands National Marine Sanctuary, and professors Bruce Kendall, Jeff Dozier, Chris Costello, and Mike McGinnis of the UC Santa Barbara Donald Bren School, for their extensive guidance and contributions throughout our study.

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EXECUTIVE SUMMARY

1. Introduction

Human activities modify marine ecosystems all too frequently in ways that reduce the provision of ecological goods and services. Fishing is one activity that can have dramatic and negative impacts on the marine environment (Jackson et al. 2001). An encouraging trend in fisheries management is the development of an ecosystem-based approach, the basis of which is the integration of physical, biological, ecological, and human social dimensions with adaptive learning in spatially-explicit models for management (Hall and Mainprize, 2004). One component of Ecosystem-Based Fishery Management (EBFM) that is rarely considered in traditional fishery management is the consideration and proactive management of recreational fisheries that can make up a significantly large proportion of total fisheries catch (Coleman et al., 2004). A greater understanding of the biological impacts and dynamic drivers of recreational fisheries move management agencies closer to EBFM. The Intergovernmental Oceanographic Commission (IOC) Inter-Agency Marine Fisheries Working Group (2002) suggest that the long-term management objective of delivering optimal fishery yields (in contrast to maximum sustainable yields) must be combined with maintenance of ecological biodiversity as one of six principles of EBFM. Regulatory mechanisms capable of delivering optimal yields over the long-term should not compromise other marine species or habitats, regardless of economics priorities (Hilborn et al. 2004). However, optimal yields of target species harvested in both commercial and recreational fisheries cannot be estimated unless both types of fisheries are monitored effectively and harvest rates are accurately estimated. To date, the integration of commercial and recreational fishery management is limited in part by the dearth of information about recreational fisheries.

Rates of harvest from open access recreational fisheries are difficult to quantify due to the combination of diffuse participation, variance in local-scale regulation, and uncertainty in estimates of fishing effort. Recent work estimates recreational harvest accounts for as much as 64% of total landings for some fisheries but conservative estimates place worldwide recreational landings at approximately 10% of total fish landed when large industrial fisheries (i.e. Pacific sardine) are excluded (Coleman et al., 2004). Recreational fisheries for California spiny lobster*, Panularis interruptus,* may account for an estimated 30% of total landings (Barilotti, 2001) but the actual value is unknown. The California Department of Fish and Game (CDFG) recommended “an investigation of spiny lobster population dynamics [to] assess the magnitude of the fishery…and investigate the adequacy of existing gear regulations” (Duffy, 1973). The investigation also noted that very little quantitative information was known about the recreational fishery, thus making it impossible to estimate what proportion of the total fishery it represented. Despite this recommendation, no attempt was made to accurately estimate harvest for the recreational lobster fishery until our study.

The California spiny lobster is the subject of lucrative commercial and recreational fisheries in southern California. In 2004, the commercial fishery for *CA* spiny lobster landed 928,302 pounds at a value of $6,629,297. Ports in the Santa Barbara region, the northern most sector of the fishery, landed 396,350 pounds at a value of $2,935,470, approximately 43% of the total lobster CA fishery in 2004 (CDFG, 2004). Data on recreational effort (i.e. number of participants, number of trips, and harvest) is collected from Commercial Passenger Fishing Vessels (CPFVs) logbooks and the California Recreational Fishing Survey (CRFS) Angler License Database (ALD) telephone survey (Horeczko, *personal communication*). Because these methods sample only a fraction of the total recreational fishery, deriving an accurate harvest estimate is difficult. The relative proportions of how participants access the fishery (i.e. CPFV, private boat, or shore) and the gear types (SCUBA diving, free-diving, or hoop-net) used among fishery participants is unknown (LaFranchi, *personal communication).* Thus, to derive accurate estimates of recreational harvest of CA spiny lobster these recreational fishery parameters must be defined.

2. Project & Methods

Based on estimates of catches from many recreational fisheries for many species worldwide, the recreational harvest of *P. interruptus* in the CA probably has a significant impact on the population dynamics of spiny lobsters through the reduction in adult abundance and population reproductive capacity, and the modification of population size-structure and sex ratio. The recreational fishery may therefore have an important influence on the commercial fishery, and vice-versa. A greater understanding of recreational harvest and the factors that influence spatial and temporal variation in the fishery will assist management agencies, especially the Department of Fish and Game, in managing for long-term sustainability and developing ecosystem-based management policy and practice.

Primary objectives of our investigation were to estimate the harvest of the lobster recreational fishery in the Santa Barbara Channel region, and to describe the fishery's behavioral dynamics (who, why, how, and when participants fish for lobster). We also sought to enhance conservation practices in management by exploring alternative conservation management practices for CA spiny lobster, principally the feasibility and support for a lobster stamp program as a means to define and quantifying the fishery. Finally, we wanted to create a replicable data-gathering and analysis system that will further refine current descriptions of the fishery.

To balance our goals of conducting a rigorous analysis with a broad geographic scope and strategic spatial resolution, we limited our investigation to Santa Barbara County and Ventura Counties. This region encompasses a nearshore coastal and a northern Channel Islands fishery for spiny lobster. Fishery participants in this region use a mix of harvest techniques including hand collection by scuba divers and free divers, and hoop-nets deployed from small boats, which is a relatively new and increasingly popular technique. Recreational fisheries have significant direct impacts on the viability of many marine fishes, invertebrates, and even mammals. Like commercial fisheries, they can also affect marine species indirectly through habitat degradation or destruction, modification of marine food webs, and reduction of water quality. In general, it is imperative that management evolve to enhance fishery sustainability and reduce the myriad of direct and indirect fishery impacts on marine systems (Botsford et al., 1997; Jackson et al., 2001). A promising alternative to conventional fishery management is an ecosystem-based approach that includes development of spatially-explicit fisheries stock assessment and conservation interventions (e.g. marine protected areas and reserves), improved understanding of species-habitat-human interactions, recognition that multiple natural and anthropogenic processes influence marine species and ecosystems, and inclusion of economic, social, government, and management reform. Assessing the effects of recreational harvests is part and parcel of an ecosystem-based approach. The recreational harvest of CA spiny lobster may substantially impact local populations, and thus ecosystem structure and function. In Santa Barbara and Ventura Counties, assessing the ecosystem effects of recreational fisheries is of great interest to the Channel Island National Marine Sanctuary (CINMS) and the CDFG, who are charged with managing the region's marine species and ecosystem. The CDFG is directly tasked with the management of the spiny lobster and as such has stock in our investigation in its quest to create methods for the proper description of the fishery.

We developed and tested a set of stated and revealed preference surveys in an effort to create a rigorous and replicable data-gathering and analysis system as a tool to quantify and describe the fishery. We tested both the stated-preference method (data relying on recollection or preference) and the revealed-preference method (actual data), to complement the weaknesses of one data-collection method with the strengths of the other, thereby creating a more reliable fishery-descriptive data-set. The surveys are the primary data-gathering tools of our system, yet the system is also made up of data-analysis methods, harvest quantification models, and a questionnaire designed to gauge the fishery's support for lobster conservation efforts (Lobster Stamp Program). As such, the data-gathering and analysis system serves to collect data and synthesize it; creating a process to define, describe, and quantify the fishery.

Our investigation can thus be divided into four principal sections:

1. Recreational harvest
2. Fishery socio-economic and behavioral dynamics
3. Lobster stamp program
4. Data-gathering and analysis system

3. Results

We produced initial estimates of fishery size and harvest to address uncertainties in estimates of participation for the California recreational fishery, and uncertainties in the pressures these fishing groups place on local populations. Current approximations of the number of recreational lobster fishermen in the Santa Barbara region were based on fishery effort data provided by the Pacific States Marine Fisheries Commission (PSMFC) Recreational Fisheries Information Network (RecFIN) and CDFG license sales statistics. Derived estimates ranged from 3,683 to 8,655 fishermen, with a predicted median of 6,109. Preliminary estimates of effort and fishing efficiency by gear type were derived from our survey of stated behavior, and used in a model to approximate the recreational harvest (Hrec) in the region based on a static model of recreational harvest. The collected survey data was assumed to display inherent bias toward fishermen taking a greater number of trips each season. In other words, there is inherent bias in soliciting information from recreational fishermen that are more likely to be surveyed, because they take more trips throughout the season. Thus you are more likely to capture fisherman that take more trips per season than the average recreational fisherman. Two models were formulated (with and without incorporating bias) to predict annual rates of harvest generated by this fishery.

Over the range of estimates of fishery size, recreational harvest varied from approximately 5,000 to 15,000 lobsters harvested during the 2004/2005 season. Scuba divers accounted for the majority of harvest (73.8%), while users of free diving gear and hoop-nets respectively accounted for 16% and 10.2% of total harvest.

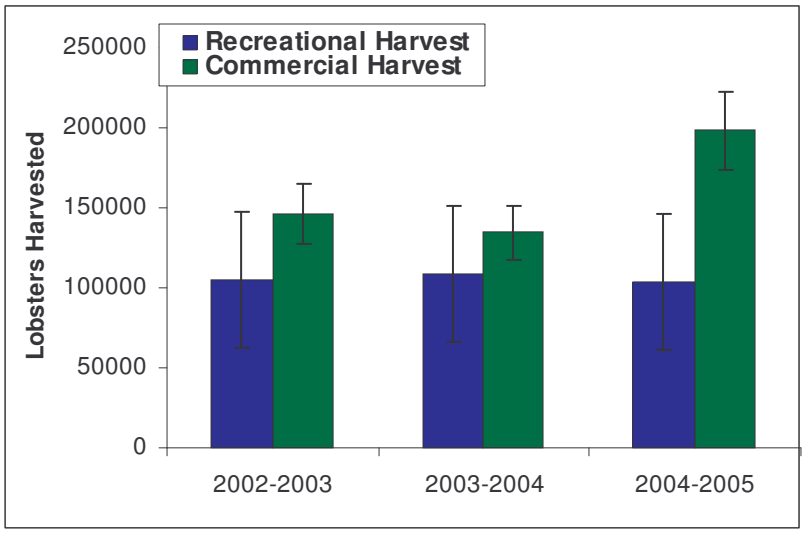

Figure 0-1: Temporal trend in recreational and commercial harvest in the Santa Barbara Channel region (Using the base model)

When combined with commercial landings, recreational harvest may represent approximately 20% to 61% of total landings, however these figures are assumed to overestimate harvest since data is biased towards respondents by gear-type and towards fishermen taking a greater number of trips each season.

Incorporating sampling bias into the recreational harvest model resulted in significant reductions in harvest estimates, as recreational fisheries were predicted to account for 8% to 22% of total harvest.

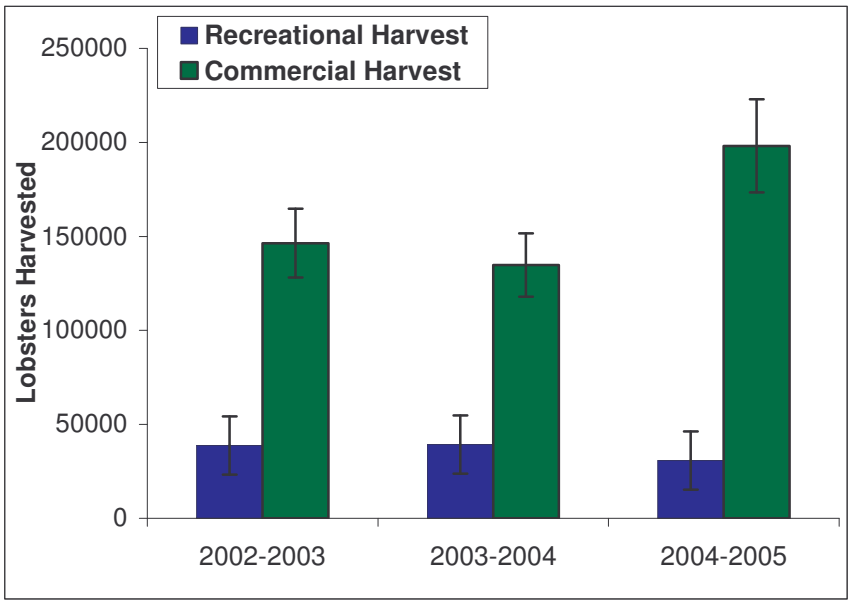

Figure 0-2: Temporal trend in recreational and commercial harvest in the Santa Barbara Channel region (Using the bias-incorporated model)

The distribution of harvest by gear type also changed significantly when survey bias was considered. Scuba divers still accounted for the majority of harvest (67%) but free divers increased to 29% and hoop-net fishermen to only 4% of harvest. Our results clearly indicate that the recreational fishery accounts for a substantial portion of lobster harvest in the Santa Barbara Channel region, and that this proportion is similar to other estimates made in a wide-variety of marine fisheries worldwide. Our results thus strongly support the general consensus among managers that the California Department and Fish and Game, in concert with stakeholders, should develop improved methods for monitoring and regulating the recreational lobster fishery in southern California.

To complement fishery harvest estimates, we collected fishery socio-economic and behavioral parameters. The critical first step in defining a fishery involves identifying its behavioral components (when, how, why, and where participants go fishing). Preliminary results presented in Table 0-1 yielded an initial socio-economic and behavioral description of the fishery:

Table 0-1: A preliminary description of the fishery's socio-economic and behavioral parameters

Socio-economic and Behavioral Parameters	Most common answer (% of respondents)
When	OCEAN WATER CLARITY (thus visibility for divers) (42%)
How (*i.e.* gear type)	Enjoyment- Ease of use (60%)
Why	Food (42%)
Where	Chance of Finding Lobsters (20%)
Years Fishing	11 years (mean)
Age	45-59 years old (40%)
Employment Status	Full Time (76%)
Income	Over $80,000 per yr. (31%)
Travel Distance	Under 10 miles (36%)

Identifying behavioral tendencies of the recreational fisherman will provide the CDFG with a valuable tool for defining and assessing the socioeconomic drivers of the fishery. This will create a better understanding among regulators on what motivates fisherman, and could potentially lead to better estimates of present and future recreational harvest and fishery participation.

Results from our survey also indicate that there is general support within the fishery for greater lobster conservation and management. We asked participants if they would support a lobster stamp program, in which fisherman would purchase a seasonal stamp permitting them to fish for lobster. These funds would be used for research to help quantify the number of recreational lobster fishermen and finance efforts to further define and understand the fishery. We found that 64% of the survey participants support a lobster stamp program and 36% of the respondents did not. 38% of respondents stated they supported the stamp program because it would improve management. 14% said they did not support a stamp program because it would increase fishing costs. Of those who did support stamps, the mean price they were willing to pay for a stamp was $7.

The methods we used to create the recreational harvest model, socio-economic and behavioral profile, and lobster stamp support were assembled to form a data-gathering and analysis system that CDFG should considering adopting for managing the CA spiny lobster recreational fishery. Our analytical system includes an evaluation scheme to assess the effectiveness of each outreach method, thus gauging the success of our survey efforts. Each survey outreach method was classified according to its respective rate of return from respondents. The effectiveness of each survey outreach method was given a qualitative ranking according to its approximate rate of return from respondents. An effectiveness level of “High” warranted a 40% return of surveys from respondents. A 20% - 40% return from respondents was given an effectiveness level of “Medium”, and any method that returned less than 20% of the surveys was given an effectiveness level of “Low.” The survey methods that were given a high effectiveness level were “In-person” administered surveys on charter boats and dive clubs. Other survey methods that were employed (intercept, workplace, e-mail, telephone, dive shops, online survey) returned medium to low return rates, and were subsequently removed from consideration as viable data-collection methods.

4. Summary and Recommendations

Our quantitiave examination of the recreational fishery for the CA spiny lobster in the Santa Barbara Channel region provides information, data, and tools for the CDFG and others to advance Ecosystem-Based Fishery Management (EBFM) practices in our marine coastal ecosystem. A key element in EBFM is assessment and regulation of recreational fisheries that often account for a substantial portion of resource exploitation as well as economic gain. Our results indicate that the recreational harvest of lobster accounts for 10-22% of the total catch of this important target species; that the level of recreational harvests may increase through time as the number of participants increase and more people begin to use non-diver (i.e. hoop-net) fishing devices; and that there is support among fishery partcipants for greater levels of management and conservation. Our results reveal substantial local support for lobster conservation efforts through the implementation of a lobster stamp program, which is further supported by the fishery's willingness to pay for such a program. CDFG can use these data form a stamp program to estimate levels of harvest, to track changes in harvest techniques and the spatial distribution of effort, indentify the socio-economic drivers of the fishery, and gauge the level of support for new management practices. Thus, our survey tool provides the means to manage adaptively through the use of estimates of fishery harvest to compliment the aforementioned socio-economic and behavioral dynamics of the fishery. Further resolution and insight into fishery participant socio-economic descriptions, and fishery effort and harvest may be gathered through continued use of and improvements to our survey methods, models, and analytical tools. Such improvements will create an even more rigorous method to define and qauntify the fishery. Our findings can be used by the CDFG and other regulatory agencies to further develop and improve management practices for CA spiny lobster and perhaps other species taken in recreational fisheries. Therefore, we propose the following set of recommendations be considered by the CDFG who should implement the subsequent action plans.

Recommended Action Plan

PLAN A: Further test our lobster stamp findings by incorporating a stamp support question in their California Recreational Fishery Survey (CRFS) questionnaire. If results of this questionnaire also indicate the majority of respondents support a stamp program and improved management, the CDFG should move to develop and initiate a stamp program that includes our survey and harvest estimate model as a means of monitoring the recreational fishery and generating revenue to be used for sole purpose of managing the lobster fishery.

PLAN B: If the lobster stamp support cannot be validated, CDFG should initiate our data-gathering and analysis system using the least biased methods (intercept and online surveys). This will allow for a more extensive description of the fishery than we conducted, and may foster further support for the lobster stamp program.

PLAN C: If Plan A or Plan B cannot be implemented, distribute the survey through the most cost-effective methods, which include distributing surveys at dive club meetings, dive shops, charter boats, and known fishery participants. This plan will further our investigation's preliminary description of the fishery, and may lead management agencies towards improved fishery management.

These methods will yield some bias which can be accounted for using bias-corrected calculations of the number of recreational fishermen using revealed preference survey methods rather than stated preference surveys, or focusing on a particular attribute of the fishery such as the spatial structure of harvest, the socio-economic and behavioral drivers of the fishery, and/or increased resolution in the dynamics of harvest by gear type.

I BACKGROUND

I.1. Introduction

It is now widely accepted that there is an urgent need to reduce harvest pressure from modern industrialized fishing practices (Myers & Worm, 2003; Zeller & Pauly, 2004). There is considerably less agreement regarding how to minimize both fishing mortality and the indirect impacts of harvest practices (i.e. bycatch) to ensure sustainable fisheries while providing long-term economic utility to consumptive users (Browman & Stergiou, 2004). Unfortunately, it has become increasingly commonplace to direct responsibility of numerous fishery failures (e.g. New England groundfish, North American abalone, Argentinean Hake; Hilborn et al., 2005) on the ineffectiveness of existing management practices (i.e. single species models and the concept of maximum sustainable yield; Mace, 2004) and lack of sufficient scientific data (Browman & Stergiou, 2004) rather than focus attention on the attributes of a growing number of economically and biologically successful fisheries (e.g. New Zealand lobster, Canadian sablefish, West Australian rock lobster, Tasmanian abalone; Hilborn et al., 2005; Mace, 2004).

The primary determinants of fishery success (stressing biological and economic sustainability) often rely on the institutional structure of fisheries (Hilborn et al., 2005). Progressive institutions charged with stewardship of marine environments are developing an ecosystem approach to fisheries management in an attempt to reduce the negative impacts of fishing (Browman & Stergiou, 2004; Cury, 2004). The foundation of ecosystem-based approaches to management therefore addresses the complexity of marine ecosystems by linking ecological processes (e.g. trophic interactions, recruitment) and anthropogenic activities (e.g. fishery harvest, urban runoff) with ecosystem-level patterns (e.g. fishery stock biomass, primary productivity) of primary concern to management (Cury, 2004). Nevertheless, a majority of existing institutional structures encourage fishermen to overcapitalize and overexploit resources as it is in the best interest of participants to maximize their own welfare. These fisheries are characterized by a race-to-fish, where individuals compete to catch a limited number of fish (Hilborn, 2005). Under this scenario, fishing pressure increases until it is no longer profitable. Traditional management has relied heavily on specific management measures (e.g. gear restrictions, maximum sustainable yield) although adaptive measures specific to access rights are present in many examples of successful fisheries. The four levels of access identified by Hilborn et al. (2005; see appendices) correspond to increasingly exclusive privileges for fishermen or groups of fishermen. Elaboration of access scenarios reconciles fisheries' short-term economic interests with long-term goals of conservation, eliminating the race-to-fish and incentive for overexploitation (Hilborn, 2004).

I.2. Recreational Fisheries and Ecosystem-Based Fishery Management

The primary principle for an ecosystem-based approach highlights and identifies the ecosystem that fisheries are managed within, and therefore requires ecosystems to be clearly defined on the basis of interactions among physical, biological, and human processes (see Hall & Mainprize, 2004). According to the Intergovernmental Oceanographic Commission (IOC) Inter-Agency Marine Fisheries Working Group (2002), the long-term management objective of optimal yields (contrary to maximum sustainable yields) must be the integrated within the conservation of ecological biodiversity. In addition, regulatory mechanisms capable of delivering optimal yields over the long-term should not compromise other marine species or habitats, regardless of economics priorities. The primary physical, biological, and socio-economic relationships occurring on an ecosystem scale must often be synthesized in models characterizing the population dynamics of target species (in association with non-target species), physical oceanographic phenomena, and the input of anthropogenic influences such as harvest pressures from commercial and recreational fisheries and the drivers of these attributes.

A greater understanding of the extent of recreational harvest and the dynamic drivers of these fisheries is a critical component of EBFM as recreational harvest often represents a significant proportion of total catch (Hall & Mainprize, 2004; Coleman et al., 2004). Nevertheless, regulation and quantification of recreational inputs are often ignored in management. Current regulatory mechanisms such as marine reserves offer a promising tool for fisheries management and the conservation of biodiversity (Hastings & Botsford, 2003), however they should not be viewed as a panacea for the drawbacks associated with contemporary fisheries management (Hilborn et al., 2004). Ecological processes such as oceanographic regime shifts and global climate change profoundly influence ecosystem-level patterns, such as stock abundance and total biomass, and occur over spatial scales orders of magnitude greater than solitary harvest *refugia*. Ecosystem patterns of interest to fishery managers may also be driven by local-scale stochastic processes such as intra/interspecific competitive interactions, behavioral and phenotypic adaptations to change, or exploitation of selected species or preferential fish size classes (Cury, 2004), without regard to zoning. A true ecosystem approach to management therefore seeks to quantify the "inputs and outputs" of harvested fisheries. By preferentially exploiting large predators in marine systems, commercial and recreational fisheries remove top-down forces in a mechanism known as fishing down the food web (Pauly et al., 1998). This effect reflects a gradual transition in landings from long-lived, high trophic level piscivorous fish to shorter-lived, low trophic level invertebrates and planktivorous fish (Pauly et al., 1998). Knowledge of the relation between ecosystem patterns and environmental and anthropogenic processes in an organized manner will allow a useful level of generalization of change in marine ecosystems (Cury, 2004; Hilborn, 2004).

The West Australian rock lobster fishery is widely recognized as one of the most successful fisheries in the world. This fishery is characterized by a long record of both a sustainable yield and high economic value, and was granted the first certification of sustainability by the Marine Stewardship Council. The fishery is regulated by the state government of Western Australia; it is a limited-entry fishery with each license holder allotted a fixed number of units of fishing effort, which are transferable among license holders (Phillips and Brown, 1989; Morgan, 2001). Units of fishing effort are defined by the number of pots, which may be adjusted annually to match incoming recruitment levels. Caputi et al. (1995) has shown that commercial harvest of western rock lobster in November though January is highly correlated with larval (puerulus) settlement indices recorded four years earlier and harvest from February through June is highly correlated with settlement three years earlier (Melville-Smith et al., 2001). Settlement is measured from puerulus caught in artificial collectors and this relationship has been documented for a number of species of *Panulirus* and *Jasus* lobsters (see Gardner et al., 2001).

An integral component of this fishery is the adequate estimation of the extent of how ecological and anthropogenic processes impact ecosystem patterns of concern, primarily stock abundance. The total commercial catch landed each season is obtained from compulsory monthly catch-and-effort returns completed by fishermen. This data is catalogued in 1° blocks, giving spatial resolution to estimates of commercial harvest (Caputi et al., 1995). Recreational fishermen in Western Australia must purchase recreational lobster-fishing licenses to legally harvest lobsters, so the number of fishermen is known. Estimates of recreational catch and effort have been made from data collected from mail surveys. Approximately 1,000 and 22,000 survey forms were mailed to a random selection of license holders at the end of the fishing season each year between 1986 and 1999 (Melville-Smith et al., 2001; Melville-Smith & Anderton, 2000). Survey respondents were asked for information regarding their fishing activity during the fishing season. Responses were used to estimate the proportion of license holders using their licenses in each season, catch and effort by fishing method (pots or diving), fishing locations, and the total rates of harvest and effort by fishermen, fishing method and region each season (Melville-Smith et al., 2001). This holistic management approach, which includes both commercial and recreational catch estimates, as well as the socio-economic and behavioral drivers of the fishery, has lead to a well managed and sustainable fishery.

I.3. Recreational Spiny Lobster Fishery in the Santa Barbara Channel and Northern Channel Islands

The northern Channel Islands and Santa Barbara Channel are located just south of Point Conception and combine to create the northern portion of the Southern California Bight. This region is characterized by complex ocean circulation patterns, high biological diversity, and is unique ecologically because it represents a biogeographic boundary between cool, northern water species and warm, southern water species (Love et al., 2002). The Channel, approximately 100km long and 50km wide with an average depth of 450m and a maximum depth of 609m is semi-enclosed by bathymetric sills separating it from the Santa Monica Basin to the east and the Arguello Canyon to the west, and is an integral part of the California-Baja California Coastal current system (Brink and Muench, 1986). The Channel Islands/Santa Barbara Channel region lies within the convergence of the colder waters of the southward flowing California Current and the warmer waters of the cyclonic circulating and northward flowing California Countercurrent. Surface waters to the north and west of the Channel are typically cool as the California Current flows south from high latitudes year-round and upwells off of Point Conception during spring and summer. At the same time, the cyclonic circulation pattern in the Southern California Bight brings warm water flowing northward along the coast, creating a complex mixing zone of eddies and gyres that power the biological and geochemical processes of the region.

The Southern California Bight is home to varied and abundant assemblages of terrestrial and oceanic flora and fauna. These plants and animals of the Bight are greatly influenced by the weather patterns and oceanic currents that introduce nutrients into the coastal zone. High nutrient concentrations are the foundation of the region's productive and species rich marine food web, promoting the growth of phytoplankton, and in turn zooplankton, which together feed a multitude of fish, invertebrate, and mammalian species.

Of primary socio-economic and cultural importance to the region are its highly productive commercial and recreational fisheries. In 2004, the commercial fisheries of the California Bight landed a grand total of 172,473,940 pounds at a value of $48,104,864; roughly 37% of the total economic value of the state's fisheries in that year (CDFG, 2004). By comparison, ports in the Channel Islands/Santa Barbara Channel region (the Santa Barbara region) landed 77,883,985 pounds at a value of $24,258,955, or approximately 18% of the entire state's fisheries economic value (CDFG, 2004). The spiny lobster fishery is the third largest fishery economically in the Santa Barbara region, behind only squid and urchin fisheries, and is the focal point of a significant socio-economic and cultural complex comprised of both commercial and recreational interests.

The California spiny lobster, *Panulirus interruptus*, is the subject of a lucrative commercial fishery along the southern California mainland and islands. This species is the target of the third most valuable commercial fishery in the Santa Barbara Channel ecosystem, exceed in value by fisheries for squid and sea urchin. Commercial landings data are obtained from fish landing receipts and logs. In 2004, the commercial lobster fishery landed 928,302 pounds at a value of $6,629,297. By area, ports in the Santa Barbara region landed 396,350 pounds at a value of $2,935,470; approximately 43% of the total California lobster fishery in 2004 (CDFG, 2004). Recreational effort data is currently only derived from Commercial Passenger Fishing Vessels (CPFVs) logbooks and the California Recreational Fishing Survey (CRFS) Angler License Database (ALD) telephone survey (M. Horeczko, *personal communication*). This survey reflects only a small fraction of recreational fishermen, and accurate estimates of harvest or fishery involvement cannot be derived from this data. Additionally, this data does not accurately describe the distribution of preferred gear types used among fishery participants (C. LaFranchi, *personal communication*).

Accurate estimates of recreational harvest of spiny lobster can be defined through a greater description of the size of this fishery and drivers of fishery involvement and harvest (Duffy, 1973). Duffy (1973) recommended a thorough investigation into the population dynamics of this species

while investigating the magnitude of fishery pressures. Spiny lobster is the only invertebrate in California that is subject to both a significant recreational and commercial fishery, and the magnitude of recreational harvest is unknown (Barsky, 2004). The initiation of a program aimed at determining the total recreational harvest of spiny lobster was listed as a future CDFG management activity that should be considered insuring the health of this resource and its associated commercial and recreational fisheries.

The CDFG recommended "an investigation of spiny lobster population dynamics [to] assess the magnitude of the fishery … and investigate the adequacy of existing gear regulations" (Duffy, 1973). Additionally, this investigation noted the fact that very little quantitative information was known about the recreational fishery, thus making it impossible to estimate what proportion of the total fishery it represented. To date, accurate estimates of large scale population dynamics including the rates of harvest from the recreational fishery are still unknown.

Rates of harvest from open-access recreational fisheries are often difficult to quantify due to the combination of diffuse participation, local-scale regulation, and a collection of other factors (Hilborn et al., 2005; Wilen, 2003). Recreational harvest may account for as much as 64% of total landings for some valued fisheries, however conservative estimates place recreational landings at approximately 10% of total fish landed when large industrial fisheries (i.e. Pacific sardine) lacking recreational fisheries are excluded (Coleman et al., 2004). Recreational fisheries for *P. interruptus* in the Southern California Bight, where involvement in commercial and recreational fisheries is significant, may account for an estimated 30% of total landings (Barilotti, 2001).

Recreational harvest of CA spiny lobster, similar to other fisheries, has the potential to decrease the abundance of legal-size adults which can lead to substantial reductions in population size and associated alteration of overall fecundity and cohort structure, potentially resulting in overfishing. There is little evidence to suggest that CA spiny lobster are overfished, but there is anecdotal evidence that size structure of the population has decreased since the 1970s and that few individuals in large size classes (e.g. individuals over 9lbs) remain (J. Richards, *personal communication*). When combined with commercial fishing, the likelihood of population-level changes may be manifested by decreasing mean size, abundance, biomass, and fecundity. Empirical evidence of this phenomenon has been documented (Iacchei et al., 2005) and the probability that a target species can be overfished increases when there is both a commercial and recreational harvest, especially when either fishery is data-poor. Beyond estimate of total dockside lands for commercial lobster fisheries in California, both commercial and recreational lobster fisheries are data poor. Uncertainty in the population and ecosystem effects of commercial and recreational lobster fishing worry fishermen, resource managers, and researchers alike (H. Lenihan, *personal communication*).

CA spiny lobster fisheries across this species' range are currently regulated by two widely dissimilar regulatory entities (U.S. and Mexico). Commercial lobster fisheries off the west coast of the United States are typified by a limited access management regime requiring the purchase of licenses to a fixed number of operators (C. Guenther, *personal communication*). Recreational fisheries in this region, on the other hand, are characterized by an open-access system, requiring the purchase of a general fishing license and ocean enhancement stamp. The ocean enhancement stamp requires fishermen utilizing marine resources south of Point Arguello to purchase an additional license with profits directed toward marine restoration. This system does not regulate the total number of licenses sold and therefore does not restrict access to the fishery. It also provides little data on the number of fishery participants and limits avenues for the collection of critical data that may describe fishery harvest and the drivers of harvest including catch rates, socio-economic profiling, and behavioral descriptions of fishery participants.

Fisheries on the west coast of Baja, Mexico have established a cooperative system that specifies resource allocation among individual communities and regions, differing significantly from the open

and limited access fisheries of the United States. Regulations have been adopted by the Federacion Regional de Sociedades Cooperativas de al Industria Pesquera (FEDECOOP) to maximize long-term sustainability of local lobster fisheries and include a voluntary secession of the fishing season corresponding with the fertilization of mature females (approximately the second week of February (M. Ramande, *personal communication*). The federation of cooperatives has been certified as sustainable from the Marine Stewardship Council, and this fishery may be described as successful from both ecological and economic perspectives.

II SIGNIFICANCE

Reliable estimates of CA spiny lobster recreational harvest rates are essential for improving management and moving towards Ecosystem-Based Fishery Management because management of the fishery is dependent upon an understanding of total annual catch of the species. The impacts of the fishery on these stocks cannot be gauged without a clear understanding of the fishery's harvest. Further quantitative assessment of the fishery's socio-economic structure is important because management is also dependent on an understanding of fishery participants and how management practices influences these drivers. Finally a better understanding of fishery-participant behavioral dynamics, specifically the when, where, why and how lobsters are harvested, provide a better and more clear understanding of how to mold management and data-gathering tools to more efficiently fit fishery parameters. Management reform is dependent on addressing these information gaps to define the fishery's ecological footprint to move management closer to an ecosystem-based framework.

This investigation adds intellectual capital to an on-going effort to improve regional fisheries management. It is the third Donald Bren School group project to provide quantitative assessment of spiny lobster fishery management, and therefore not only improves management directly by generating new ideas and models, but also strengthens a growing movement in research collaboration and co-management among stakeholders. Our investigation is thus a model for improving fisheries management in general through greater integration of willing stakeholders with varying skills, perspectives, and objectives. Finally, a significant portion of our research is designed to advance spiny lobster conservation through the introduction of a Lobster Stamp Program, that aims to improve information and data collection that can be used to monitor, manage, and model the fishery. This is the first step towards moving recreational lobster fishery management from a data-poor state to one that is data-sufficient, and eventually to data-rich.

II.1. Benefits to the California Department of Fish and Game

In its 2003 *Fishery Status Report* for the Spiny Lobster, the California Department of Fish and Game stated that "the spiny lobster is the only invertebrate in California that is subject to both a significant recreational and commercial fishery…yet the magnitude of the recreational fishery take is still unknown" (CDFG, 2003:7). The lack of recreational harvest data has concerned the CDFG for over 30 years. In 1973, a study completed by Duffy for the CDFG stressed the difficulties of deriving total harvest estimates without reliable estimates for the recreational component. The same 2003 CDFG report calls for the design of a program to determine the total recreational take of spiny lobster, and recommends that management programs "should be considered to ensure the health of this resource and of the sport and commercial fisheries."

Towards this end our investigation aims to assist the CDFG by designing a replicable data-gathering and analysis system to estimate the regional Spiny lobster recreational harvest, and to help describe the fishery's socio-economic and behavioral dynamics governing this fishery.

II.2. Benefits to the Channel Islands National Marine Sanctuary

The Channel Islands National Marine Sanctuary was established in 1980, and the network of harvest closures and MPAs were revised and implemented following the 2002-2003 lobster season. One of the primary concerns of both CINMS and the CDFG are the poorly described relative proportions of access and gear types available to the recreational spiny lobster fishery. This is principally manifested in an effort to better understand how fishermen access the fishery, and to approximate the spatial distribution of harvest within the sanctuary. Due to the manner by which this fishery is quantified and defined, an accurate description of the fishery is difficult and the current understanding vague. Fishery information is only gathered from CPFV logbooks, while private boats and shore-based fishermen remain unaccounted for. Due to the ambiguity or lack of data concerning recreational use of the Sanctuary (including recreational lobster fishing), CINMS

has begun to focus some of its energy towards defining the fishery socio-economic and behavioral factors that define and influence the use of the Sanctuary.

Our investigation worked with CINMS, Sean Hastings (CINMS Resource Protection Coordinator), and Chris LaFranchi (CINMS Social Science Coordinator) to create a socio-economic and behavioral profile of the recreational fishermen that frequent the northern Channel Islands and to assess recreational lobster harvest rates in and around the Sanctuary.

II.3. Benefits to the Fishing Community

One of the main obstacles that regulators, scientists, and management agencies face when dealing with fisheries management is the reluctance of fishermen to cooperate for fear of increased restrictions. Most fishermen are concerned that information sharing will lead to tighter regulations, initiating movement away from what is perceived to be an open-access fishery towards highly restricted system of regulation and compliance, and more recently, restricted spatial access via marine reserves. One potential technique to address such barriers is through collaborative management, whereby fishery participants are represented and empowered in the management decision-making process. Such collaboration was successfully initiated between managers and spiny lobster fishermen by the Lenihan laboratory, in part through a MESM Group Project (Abramson *et.al*., 2005).

Our project advances the Bren School's participation in lobster co-management through development of a mutually beneficial data-gathering and analysis system by which fishery stakeholders can express their opinions and concerns, while taking part in the management of their fishery. The CDFG is required by the CA Marine Life Management Act of 2004 to create a management plan for the southern California spiny lobster fishery. While the CDFG does not currently have the resources to begin the management drafting process, local researchers, such as the Lenihan Lab, and interested stakeholders have begun to research and draft a management plan. These circumstances prompt the perfect opportunity for the local fishing community to take proactive steps in the eventual management of the spiny lobster. Such a step could take the form of an adapted management scheme which includes a harvest model and a behavioral socio-economic profile based on the findings of this investigation, which is furthered by the uncovered support for a lobster stamp program.

We elected to work with the recreational fishing community to help stakeholders take an active and critical role in the growing co-management effort, specifically in the formulation of data-gathering and management recommendations. Our investigation formulated data-acquisition and analysis tools. It also collected qualitative information regarding recreational fishermen opinions and management concerns thus creating a mutually beneficial collaboration between the fishing community and fishery management agencies. The investigation will thus give the fishing community additional voice and representation in the management arena, which will allow the CDFG to make informed management recommendations.

II.4. Benefits to the Research Community

One of the primary objectives of the California Sea Grant "Is to work toward the sustainability of fisheries and fishing communities, while protecting and enhancing natural resources (CSG, 2006)." To address some of the regional challenges and to create future opportunities for sustainable resource management, Carrie Culver, Sea Grant's Ventura and Santa Barbara Regional Advisor, sits on the project's advisory board as an advisor and client. Our investigation is of interest to Sea Grant as a fishery management development tool, especially as a working example of collaborative fishery research and co-management.

III QUESTIONS

III.1. Estimating Recreational Harvest

Historically, for fisheries in general, the brunt of the public focus was centered on measuring and identifying the effects of commercial fisheries on stock depletion, bycatch, and habitat damage. However, recent studies have indicated that the recreational outputs of certain fisheries may account for as much as 23% of nationwide landings (Coleman, 2004). Therefore it is important to consider the recreational outputs of any fishery when implementing management strategies. Incorporating recreational take can improve harvest estimates for the overall fishery. Approximating the recreational take can also help management agencies design regulations to better suite these harvest estimates.

With respect to the California spiny lobster fishery, the CDFG has rather accurate estimates of the commercial landings from logbook data. The net ecological impact of the recreational harvest and commercial landings has only recently been studied (i.e. Iacheii, 2005). Although there is sufficient data on commercial and recreational fishery interactions with respect to ecosystem effects, there is limited data on the recreational outputs of the fishery. The recreational fishery has not yet been adequately quantified and defined, nor have its ecological impacts been evaluated scientifically. Therefore, an estimate of the recreational harvest of the California spiny lobster recreational fishery is important to the northern Channel Island region as a whole. Having an estimate of the recreational fishing outputs will allow for more accurate estimates of the net impact of the recreational and commercial fisheries, and lead to more efficient management of recreational fisherman. Additionally, knowing approximate harvest estimates could potentially absolve user conflicts between recreational and commercial fisherman. For these reasons an estimation of spiny lobster recreational harvest is warranted in Santa Barbara and Ventura County and the Channel Islands. Our project serves to create methods to collect data on the recreational spiny lobster harvest, and our data is destined for a dynamic recreational harvest model used to give insight into estimates of harvest of spiny lobsters.

III.2. Fishery Socio-economic and Behavioral Dynamics

To develop an understanding of the fishery's drivers we ask the following two questions: 1) What are the socio-economic (i.e. fisherman age, income, and employment status) drivers of the fishery, and 2) What are the behavioral dynamics (what, where, when, why, how lobsters are caught) of the fishery? These parameters can be used in the development of the recreational harvest model to answer questions about the variability and impact of these fishery drivers on lobster stocks and the development of management,

While establishing an estimate for recreational harvest, attempts should be made to develop a more dynamic model that describes fishing behavior. In other words, a model would enable the CDFG to estimate recreational take, and also estimate how the lobsters are being caught. For example, a dynamic recreational harvest model will estimate how many lobsters are taken per gear type within the region, and at what rate the lobsters are being harvested.

Identifying the behavioral tendencies of the recreational fisherman in a given region will provide the CDFG with a valuable insight into the socio-economic drivers of the fishery to create fishery-specific management techniques. Furthermore, this insight will help policy makers determine which aspects (i.e. gear type, harvest method, etc.) of the recreational regulation policies are currently outdated, and to develop more comprehensive management schemes that are specifically geared towards fishery socio-economic and behavioral dynamics.

III.3. Lobster Stamp Program Support

To gauge the fishery's support for lobster conservation our investigation introduced a Lobster Stamp Program and measured the fishery's willingness to pay to substantiate the level of local support for a lobster stamp program. A recreational fishing lobster stamp would mimic the California ocean enhancement stamp, in that it would be purchased in conjunction with a general recreational fishing license in the state of California. The ocean enhancement stamp serves the important function of quantifying the number of oceanic fisherman in California, and the CDFG is able to extrapolate where the licenses are sold by region and county (CDFG, 2004). If a lobster stamp were to be implemented in California it would serve a similar function; namely allowing the quantification of the approximate number of recreational lobster fisherman in California. Furthermore, if the number of recreational fisherman in the California spiny lobster fishery is reliably quantified, the CDFG can begin to utilize recreational harvest models to explain fishery trends. For example, trends in the number of fisherman entering and exiting the lobster fishery over time, or explain temporal harvest trends. This would allow management agencies to better understand the fishery and in turn help them to better manage it.

Gauging the fishery's level of support for a lobster stamp program will lend support to our investigation's data-gathering and analysis system and harvest models. Through our survey method, we can estimate the amount of local support for a lobster stamp program within the recreational lobster fishing community. The CDFG can use this data to determine if there exists enough public interest to implement a lobster stamp program. In addition to gauging the fisheries level of support for such a program, our investigation goes on to measure the fishery's willingness to pay for a stamp program. The willingness to pay data thus creates a metric to gauge support for a lobster stamp, and creates a method to approximate the level of revenue that could potentially be generated from such a program; in an attempt to validate the cost-effectiveness of such a program.

III.4. Data-gathering and Analysis System

Our fourth question asked: What are the best and most appropriate data-collection and analysis techniques to define recreational fishery harvest rates, socio-economic and behavioral dynamics, and to measure the fishery's support for a lobster stamp. To collect data to answer our first three questions (i.e. harvest, fishery dynamics, and lobster stamp support), we first concentrated on the development of a comprehensive data-gathering and analysis system based on a stated-preference paper survey.

The survey and subsequent outreach methods were developed, in collaboration with fishery stakeholders and with the help of our focus group, to be able to access all fishery participants within our target region. By implementing the data-gathering and analysis system, relevant preliminary conclusions from the data were derived, and the survey outreach methods were further refined for use and replication by our clients. In other words, the survey could potentially serve as a valuable data collection tool for continued recreational lobster fishery studies. In addition, our method can serve as a model for the quantification and description of other recreational fisheries.

IV OBJECTIVES AND DELIVERABLES

The main objectives of our project are to estimate the harvest of the recreational fishery for the California spiny lobster, *Panulirus interruptus,* in the Santa Barbara Channel and northern Channel Islands, and to describe fishery socio-economic and behavioral dynamics governing this fishery. In addition we also report on the fishery's willingness to support and pay for a lobster stamp program. Toward this end, our investigation will create a replicable data-gathering and analysis system for defining the recreational fishery drivers of harvest rates through a set of stated and revealed-preference surveys. Determining the recreational harvest of spiny lobster and the socio-economic and behavioral dynamics of its fishermen will help marine resource management agencies better understand and effectively manage the fishery and its ecosystem.

Our four major objectives are to:

1. Estimate the regional spiny lobster recreational harvest
2. Report on the preliminary description of the socio-economic and behavioral dynamics governing the fishery
3. Evaluate the support and willingness to pay for the implementation of a lobster stamp conservation program
4. Design a replicable data-gathering and analysis system

Our deliverables include:

1. A dataset from the stated-preference surveys to begin a compilation of baseline data on the Santa Barbara Channel and Channel Islands region recreational spiny lobster fishery.
2. A preliminary analysis of the above mentioned dataset which will include:
   (a) An initial estimate of the total recreational harvest
   (b) A preliminary description of the temporal and spatial trends in harvest rates and fishery attributes
   (c) An introductory identification of the fishery's socio-economic and behavioral dynamics
3. A set of recommendation action plans based on fishermen support for the implementation of a lobster stamp program.
4. A report of our survey methods and recommendations for collecting harvest and fishery socio-economic and behavioral dynamics data for the fishery.
5. A final improved version of the data-gathering and analysis system and survey (Appendix 6), and a method for replicating the survey at a larger spatial and temporal scale.

V METHODS

To create a replicable data-gathering and analysis system that is valuable for future use by marine resource managers, we decided to base our methods on a set of stated (Appendix 1) and revealed-preference (Appendix 2) surveys. The surveys are the primary data-gathering tools of our system, which is also made up of data-analysis methods and harvest quantification models. As such, the data-gathering and analysis system serves to both collect data and analyze it, creating a method by which to describe and quantify the fishery.

V.1. Estimating Recreational Harvest

When examining a combination of commercial and recreational harvests, a fixed harvest rate may be defined simply as:

$$H = H_{com} + H_{rec} + P \qquad \text{(Equation V.1)}$$

where: H_{com} = Commercial harvest (*n* landed yr $^{-1}$),

H_{rec} = Recreational harvest (*n* landed yr $^{-1}$), and

P = illegal poaching (*n* landed yr $^{-1}$).

A static model of recreational harvest based on stated fishermen behavior may be described by:

$$H_{rec} = \sum_{\tau=0}^{\infty} f_\tau \tau e_\tau \qquad \text{(Equation V.2)}$$

where: f_{total} = total # of participants in the fishery = $\sum_{\tau=0}^{\infty} f_\tau$ (Equation V.3)

f_τ = the number of fishermen taking τ trips each season,

τ = the number of fishing trips taken each season, and

e_τ = fishing efficiency by τ (# landed trip^{-1}).

Complexity may be incorporated into the static model to account for the dynamics of recreational fisheries as a factor of multiple gear types. Recreational fisheries for *Panulirus interruptus* feature three distinct gear preferences each with corresponding characteristics. Adding a gear type component to the static model creates a recreational harvest model where:

$$H_{rec} = \sum_{g=0}^{i} \sum_{\tau=0}^{\infty} f_{\tau g} \tau_g e_{\tau g} \qquad \text{(Equation V.4)}$$

where: i = # of gear types utilized by recreational fishermen

g_1 = the proportion of fishery participants who utilize scuba diving equipment,

g_2 = the proportion of fishery participants who utilize free diving equipment,

g_3 = the proportion of fishery participants who utilize hoop-nets, and

$e_{\tau g}$ = a function of the number of trips taken by fishery participants by gear type, $f(\tau_g)$.

There is much uncertainty in estimates of the degree of participation in southern California recreational spiny lobster fisheries, and this investigation aims to produce initial estimates of this parameter for the Santa Barbara region's fishery. Current approximate estimates of the number of fishermen utilizing a particular fishery may be based on finfish fisheries data provided by the Pacific States Marine Fisheries Commission (PSMFC). Recreational catch data on finfish is compiled by the PSMFC's Recreational Fisheries Information Network (RecFIN), which provides

comprehensive catch and effort data for Pacific Coast recreational fisheries. From this data, estimates of f_{total} may be derived pertaining to regional recreational fisheries for spiny lobster.

For the Santa Barbara and Ventura regions, recreational fisheries for kelp bass, *Paralabrax clathratus,* and halibut, *Paralichthys californicus,* were chosen as models for the number of fishing license holders who utilize a particular resource. The Recreational Fisheries Information Network has provided reliable effort data for fisheries of *P. clathratus*, including annual estimates of effort over the past year. Based on these data, the number of fishermen targeting kelp bass may be assumed. With the large assumption of similar dynamics within fisheries for *P. interruptus*, estimates of the number of participants in regional lobster fisheries may be derived.

CDFG records indicate that between 1,179,597 and 1,385,421 resident fishing licenses have been sold annually since 1997. In addition, a significant amount (between 153,396 and 493,281) of one and two day fishing licenses has been sold each year during this time. Non-resident licenses contributed a relatively insignificant proportion of total licenses sold (~ 10,000 – 12,000). Based on the estimated mean number of trips taken by fishery participants each season (see next section), the number of one and two day license holders was adjusted resulting in estimates of the total number of license holders to range from 1,200,946 to 1,425,177. CDFG records further indicate that sales of ocean enhancement stamps have ranged from 251,986 to 315,976 since 1997, and it may be inferred that approximately 20.5% to 22.9% of license holders have purchased stamps and in fact fish in marine regions. Data on ocean enhancement stamp sales by region show that 7.39% and 3.39% of stamps are sold in Ventura and Santa Barbara counties respectively. Using the purchase of the ocean enhancement stamp as a proxy for potential fisherman, regional approximations of potential total fishery size (all marine sport fishing, including lobster) may be assumed (Figure V-1).

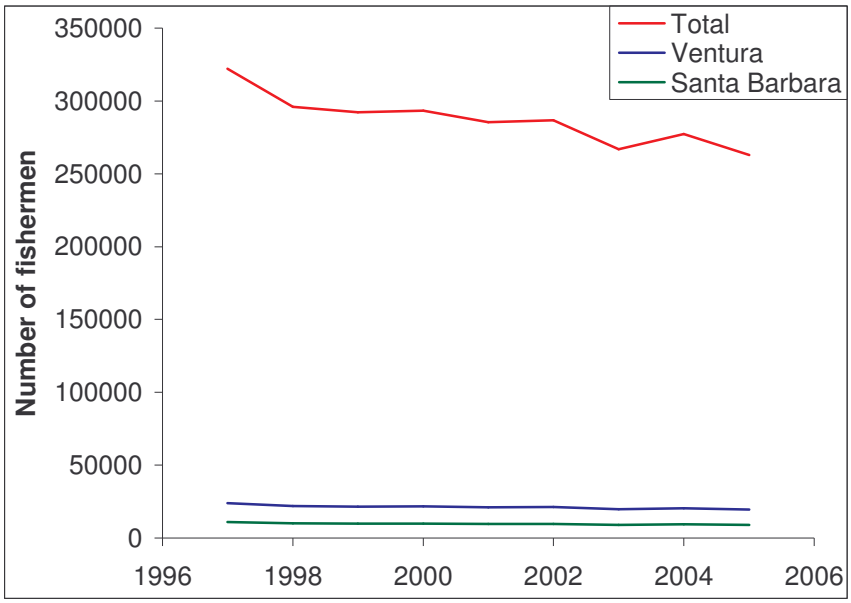

Figure V-1: Total and regional approximations of the number of fishermen utilizing marine resources

The distribution of the number of trips taken by survey respondents will be used to infer the behavioral dynamics of fishery participants. Participants in the fishery may be grouped by their preferred gear type, and there may be variance in the number of trips taken by participants favoring different gear types. Previous season data is used rather than a mean of all seasons to add credibility to estimates based on stated-preference.

Analysis of variances in τ (# trips per year) by gear type is accomplished by survey question 11. If survey respondents state use of more than one gear type over the course of the fishing season, for

the purposes of determining τ_x, each response to subsets of survey question 11 (if > 0), multiplied by survey question 10, is considered an estimate of the average number of lobster fishing trips per season specific to the respondents preferred gear type. The distribution of trips by gear type can then be fixed by the number of survey responses to yield a probability of observing a fisherman taking τ trips each season.

The distribution of fishery involvement (measured as trips taken each season per fishery participant) may be variable across gear types, therefore the parameters *f* and τ are evaluated by gear type. In addition, the survey tool utilized may attract bias as the fishermen surveyed/encountered are likely to take a greater number of trips each season. Therefore methods will be used to determine recreational harvest under two scenarios (the first acknowledging survey bias and the second not considering this bias). This bias is corrected based on methods derived from the contingent valuation literature (see Thompson & Seber, 1996; Thompson, 2002), and assumes correlation between probability of observing a fisherman with the number of trips taken by that fisherman each season.

The survey tool used in this investigation asked respondents for the average number of fishing trips taken each season since 2003. The distribution of responses to this question therefore reflects the probability of observing a fisherman taking τ trips each season within the surveyed population. Since the survey was directed towards known fishermen and fishing groups, there is the potential for significant bias toward fishermen who take a greater number of trips each season. A direct relationship between the probability of observation and the number of fishing trips taken each season is assumed (see appendix for example). The probability of observing *(Pr{observation})* a fisherman taking τ trips each season according to the survey can therefore be described by:

$$\Pr\{observation\} = \frac{f_\tau \tau}{\tau_{total}} = \frac{f_\tau \tau}{\sum_{\tau=1}^{\tau_{\max}} f_\tau \tau} \qquad \textbf{(Equation V.5)}$$

where: $$\tau_{total} = \sum_{\tau=1}^{\tau_{\max}} f_\tau \tau = f_{total} \times C \qquad \textbf{(Equation V.6)}$$

and $\tau_{\max}$ = the maximum number of trips taken by a fisherman each season.

C, in equation V.6, is a constant describing the relationship between the total number of fishermen and the total number of trips taken each season. This constant may also be described as a measure of survey bias. An ideal sampling scenario will utilize a random sample of fishermen sampled at a constant rate, such as the telephone survey administered to one in twenty purchasers of recreational fishing licenses i.e. lobster stamp program. The probability of observing a fisherman taking τ trips each season using a random sampling effort is described by:

$$\Pr\{observation\} = \frac{f_\tau}{f_{total}} = \frac{f_\tau}{\sum_{\tau=1}^{\tau_{\max}} f_\tau} \qquad \text{(Equation V.7)}$$

The bias incurred when using a targeted survey may therefore be described as a function of τ,

where: $$bias_\tau = \frac{f_\tau \tau}{\sum_{\tau=1}^{\tau_{\max}} f_\tau \tau} - \frac{f_\tau}{\sum_{\tau=1}^{\tau_{\max}} f_\tau} \qquad \text{(Equation V.8)}$$

Without knowledge of the true distribution of the number of trips taken by fishery participants each season, the total number of fishing trips taken by all fishery participants cannot be known. Logical estimates of survey bias may be derived however, through analysis of the survey response. It is logical to assume that τ follows a log-normal distribution among both survey respondents and the true populations of recreational fishermen. The difference in shape between these distributions can then describe the survey bias (Costello, *personal correspondence*). Although exact predictions of survey bias are impossible to predict, the number of fishermen taking τ trips each season (f_τ) may be predicted by transforming equation V.5, to the following:

$$f_\tau = \frac{\Pr\{observation\} \times f_{total} \times C}{\tau} \qquad \text{(Equation V.9)}$$

The constant *C*, noted previously as a measure of survey bias, may be described as the bias index (BI). Equation V.9 may therefore be rewritten as:

$$f_\tau = \frac{\Pr\{observation\} \times f_{total} \times BI}{\tau} \qquad \text{(Equation V.10)}$$

Since the bias index describes the relationship between the total number of trips taken by all fishermen and the total number of fishermen, estimates may be derived with a known (albeit biased) distribution of trips. Since the sampled population is more likely to take a greater number of trips each season, neither the mean nor median number of trips taken each season by survey respondents can be used to predict the true mean. The most frequent response (mode), fixed by a measure of observation success (here measured as $\ln\tau$), yields logical estimates of the relationship between f_{total} and τ_{total}, and in effect an accessible estimate of BI. Since this parameter is assumed to be variable across gear types used by fishery participants, values of BI will be derived in accordance to gear type.

Correlation between τ and *e* will be used to infer fishing efficiency based on the number of trips taken per year. Survey question 12 asks respondents to estimate the average number of lobsters taken per trip by gear type. Again, for the purposes of determining e_x, each response to a subset of question 12 (if > 0) is considered an estimate of the average fishing efficiency specific to the respondents preferred gear type. Since units of effort used in this investigation are the number of trips taken by fishery participants each season, fishing efficiency is measured as the number of legal-sized lobsters caught during one fishing trip. Fishing trips are single days, and multiple day trips are included as multiple trips.

Once effort (f_τ) and fishing efficiency (e_τ) parameters are derived specific to τ and gear type (*g*), estimates of recreational harvest may be derived using equations V.4 and V.9. Additional complexity may be added to the model to account for fishery behavioral dynamics such as seasonal changes in preferred gear types, however quantitative investigations of such phenomena is outside the scope of this project. Qualitative information pertaining to fisherman behavior and preferences may augment the development of future quantitative investigations. The primary objectives of the stated-preference survey are initial estimates of parameter values for the static recreational harvest model with the added gear type component.

Temporal trends in rates of harvest from recreational fisheries are derived by replicating the questions used to parameterize the static model based on past years' data. The survey relies on respondents' stated behavior from the 2004-2005 and 2003-2004 seasons, in addition to estimating *averages* for questions 10-14 for all prior seasons. The significance and accuracy of stated-preference/behavior data is often sacrificed when the timescale of data questioned exceeds approximately 1-2 years (LaFranchi, *personal communication*).

V.2. Fishery Socio-economic and Behavioral Dynamics

V.2.i. Socio-economic and Behavioral Dynamics Qualitative Summary Statistics:

For the survey questions pertaining to fishery socio-economic and behavioral dynamics, *i.e.* questions 1 through 7, 9, 12 and 15 to 18, summary statistics were completed.

We calculated the average number of years fishing for all responses given to question 1, including non-responses. In addition, we totaled the number of recreational lobster fishermen who had fished for more than two years. The remaining responses were an indication of the number of the sample population who had fished for lobsters for less than two years. This gave us the total number of recreational lobster fisherman who had fished for lobster prior to the establishment of MPAs in the Northern Channel Islands.

Questions 2 and 3 were open-ended questions that reflected what factors determine why they fish, and what factors determine where they fish, respectively. The answers respondents gave were coded, and the frequencies of each answer for both questions 2 and 3 were used to summarize the responses.

Question 4 was crafted to gather data on the use of MPA areas prior to establishment. To determine whether fishermen had been displaced after the implementation of MPAs, we calculated the frequencies of “yes” or “no” responses. As far as what MPA they used to go lobster fishing to, we looked at the frequency for each location mentioned.

Question 5 asked respondents if the establishment of MPAs had increased their recreational use. From the answers, we calculated the frequencies of “yes” or “no” responses and we calculated the percentage of responses that indicated an increase in recreational experience.

Question 6 was an open-ended question that enquired about the factors that affect what gear-type they use to go fishing. From the answers, we tabulated the frequencies of each response.

Question 7 was “do you switch lobster fishing gear during a given season? If yes, why and when?” To evaluate the responses to this question we found the frequencies of “yes” and “no” responses, and tabulated the frequency of each reason given for switching gear.

Question 9 addressed the factors that influence when people go fishing. For this question, we found the category that was given the highest ranking among all respondents.

Questions 15 – 18 solicited information on the socio-economic profile of the recreational fishery in the target region. The data analysis was treated somewhat differently from the previous sections. The socio-economic data was primarily used in the regression analysis. Taking this into account, summary statistics were calculated to uncover any bias in the sample with respect to socio-economic variables. Therefore, for each socio-economic question (15-18) we tabulated the frequency of answers for each category, thus giving an indication if our sample is bias towards a particular age, employment status, income, or distance traveled to most frequented fishing areas.

V.2.ii. Socio-economic and Behavioral Dynamics Regression Analysis

A. Average Number of Trips:

Regression analysis was used as a data analysis tool to investigate what factors solicited in the survey affected the number of trips taken during the 2004-2005 season. To meet this objective a stepwise regression analysis was completed using the JMP 5.1.2 Statistical Discovery Software. Rather than analyzing the data in code form, the data had to be reentered into original answer format. Depending upon how each question was solicited in the survey, the answers to each respective question were treated as ordinal, continuous, or categorical. The dependent variable (number of trips) was treated as continuous data. The data that was likely to affect the number of

trips taken by recreational fisherman was solicited from questions 4 – 8 and questions 15 – 18, and was used in the regression analysis.

As a result of the selected data, the regression analysis used following model:

$$\#trips = \alpha_0 + \alpha_1[\#\ years\ \ fishing\ ] + \alpha_2[age] + \alpha_3[income\ ] + \alpha_4[travel\ ] + \alpha_5[employment\ ] + \alpha_6[recreation\ al\ use] + \alpha_7[geartype\ ] + \alpha_8[MPA] + \varepsilon$$

Where:

 # trips: number of trips is the dependent variable as a function of survey data.

α_0**:** y-intercept of the model.

α_n**:** independent variable estimate coefficients

[#years fishing]: average number of years fishing as a continuous independent variable

[Age]: age of fisherman as continuous independent variable

[income]: stated income as an ordinal independent variable

[travel]: stated distance of travel to the most frequented fishing spot as an ordinal independent variable.

[employment]: stated employment status as a categorical independent variable

[recreational use]: stated recreational use after the implementation of MPAs as an independent ordinal variable

[Gear type]: stated gear type used as categorical independent variable

[MPA]: stated previous use of areas designated as MPAs as an ordinal independent variable

The coefficients preceding α_n in the model reflect each independent variable's respective effect on the average number of trips taken. To first determine which dependent variables had a significant effect on the number of trips, a stepwise regression analysis was used to determine which factors or combination of factors were statistically significant to include in the regression equation. Using only the data that was statistically significant at the 95% confidence interval ($p<0.05$), an ordinary least squares regression was done to create a model indicating which independent variables from the data had an effect on the number of trips a recreational lobster fisherman takes.

B. Gear Type Logistic Analysis:

A logistic regression analysis was used to uncover which factors from the collected survey dataset influence the gear type used by recreational lobster fisherman. As in the previous regression analysis, the JMP 5.1.2 Statistical Discover Software was used. Although using the same data table as the ordinary least squares analysis, the data for the gear type had to be treated differently. A logistic regression provides insight into which independent variables are associated with explaining changes in categorical dependent variables. Since the dependent variable is categorical, a logistic regression was used to find which independent variables from the survey data influence gear type. The data solicited from question 6, dealing with gear type, was an open-ended question, and therefore was coded for all the different answers that were given (hoop net, free diving, and SCUBA diving). This data was treated as categorical dependent variables. Based on the number of responses given by the sample population, each gear type was included in the analysis. Question 12 asks respondents to state the number of lobsters they took using each specific gear type. We plugged the most commonly used gear type data in the regression analysis section as a categorical independent variable. The data that was expected to affect the gear type used by recreational fisherman in the sample population was included in the model, represented by the following equation:

$$geartype = \beta_0 + \beta_1[\#\ years\ \ fishing\ ] + \beta_2[age] + \beta_3[income\ ] + \beta_4[travel\ ] + \beta_5[employment\ ] + \beta_6[recreation\ al\ use] + \beta_7[\#trips\ ] + \beta_8[MPA] + \varepsilon$$

Where:

Gear type: stated-preference categorical dependent variable

β_o**:** y-intercept estimate of the regression model

β_n**:** independent variable parameter estimate coefficients

[# of years fishing]: average number of years fishing as a continuous independent variable

[Age]: age of fisherman as a continuous independent variable

[income]: stated income as an ordinal independent variable

[travel]: stated distance traveled to the most frequented fishing spot as an ordinal independent variable.

[employment]: stated employment status as a categorical independent variable

[recreational use]: stated recreational use after the implementation of MPAs as an independent ordinal variable

[Gear type]: stated gear type used as a categorical independent variable

[MPA]: stated previous use of areas designated as MPAs as an ordinal independent variable

The coefficients preceding β_n in the model reflect the magnitude of effect each independent variable has on gear type. To first determine which dependent variables had a significant effect on gear type, a stepwise regression analysis was used to find which factors or combination of factors were statistically significant to include in the logistic regression equation. Only parameter estimates that were statistically significant at the 95% confidence interval ($p<0.05$) were included in the logistic regression model.

V.3. Lobster Stamp Program Support

When developing the question to gauge support for a lobster stamp program in the target region we also chose to assess the respondents' willingness to pay for such a program. Included in the question was a short description of what a lobster stamp program would encompass, giving respondents an idea of how lobster stamp programs function, and how it would be implemented. Due to a limited amount of space on the survey, a full description of a lobster stamp program was not included. However, the short description given in the text of the survey was created to avoid bias in elicited responses.

V.3.i. Lobster Stamp Support Summary Statistics:

To get a general sense of support for a lobster stamp program in the target region basic summary statistics were first implemented to analyze the collective responses. Looking at the dichotomous choice question first, the number of "yes" responses and the number of "no" responses for support for the program was totaled. The responses to the open-ended question of "why or why not" respondents support a lobster stamp program were used to develop a percentage breakdown of the reasons for support and against support of the program within the sample population.

Included in the summary statistics for support of the lobster stamp program was the mean willingness to pay calculations for all responses. A willingness to pay value was calculated for all responses given to the dichotomous choice question. In other words, the willingness to pay values were aggregated for a mean calculation based on "yes" and "no" responses for support of the lobster stamp program. A separate mean willingness to pay was determined for respondents that indicated approval for the implementation of a lobster stamp program. The separate mean willingness to pay values were used as a tool to justify general support of the lobster stamp program within the target region based on the sample size of the stated-preference paper survey.

V.3.ii. Lobster Stamp Support Regression Analysis:

In addition to basic summary statistics, regression analysis was completed to reveal any variables solicited in the survey that could possibly have an impact on support for the lobster stamp or the mean willingness to pay. To determine which variables have an effect on support for the lobster stamp program a logistic regression was completed for the ordinal (yes or no) data collected through the survey. In addition, an Ordinary Least Squares (OLS) regression analysis was done to see which variables influence the willingness to pay for all respondents, and solely for "yes" respondents. As used in the Fisherman Behavioral Dynamics Regression analysis, the regression analysis was done using JMP 5.1.2.

A. Logistic Regression on Stamp with Dependent Variable as Nominal (yes/ no)

Based on the responses for support of the lobster stamp program, the logistic regression analysis was used to determine which parameters collected by the surveys may have influenced responses. For example, the aggregate age of a respective fisherman may have an effect on whether or not they agree to support the lobster stamp program. It was predicted that the regression analysis would give the following model:

$$Stamps = \gamma_0 + \gamma_1[\#\ years\ fishing] + \gamma_2[age] + \gamma_3[income] + \gamma_4[travel] + \gamma_5[employment] + \gamma_6[recreational\ use] + \gamma_7[geartype] + \gamma_8[MPA] + \varepsilon$$

Where:

[Stamps]: ordinal dependent variable representing support for the lobster stamp program

γ_o: y-intercept of the model

γ_n: independent variable coefficient estimates

[# of years fishing]: average number of years fishing as a continuous independent variable **[Age]:** age of fisherman as continuous independent variable

[income]: stated income as an ordinal independent variable

[travel]: stated distance traveled to the most frequented fishing spot as an ordinal independent variable.

[employment]: stated employment status as a categorical independent variable

[recreational use]: stated recreational use after the implementation of MPAs as an independent ordinal variable

[Gear type]: stated gear type used as a categorical independent variable

[MPA]: stated previous use of areas designated as MPAs as an ordinal independent variable

The coefficients preceding γ_n in the model reflect each independent variables respective influence on the decision to support a lobster stamp. To first determine which dependent variables had a significant effect on support for the stamp, a stepwise regression analysis was used to determine which factors or combination of factors were statistically significant to include in the regression equation. Using only the data that was statistically significant at the 95% confidence interval ($p<0.05$), logistic regression was done to create a model indicating which independent variables from the data had an effect on the amount of support for a lobster stamp program.

B. OLS Regression on WTP as a Dependent Variable

Based on the stated-preference responses to the willingness to pay question the OLS regression analysis tool was used to determine which factors solicited from the survey may have affected the monetary value indicated in responses. For this regression equation, all responses that did and did not indicate support for a lobster stamp were included. The following regression equation was predicted to reflect the factors solicited from the survey that affected an indicated willingness to pay:

$$WTP = \lambda_0 + \lambda_1[\#\ years\ fishing] + \lambda_2[age] + \lambda_3[income] + \lambda_4[travel] + \lambda_5[employment] + \lambda_6[recreational\ use] + \lambda_7[geartype] + \lambda_8[MPA] + \varepsilon$$

Where:

[WTP]: the willingness to pay value as the dependent continuous variable (all responses)

λ_o: y-intercept of the model

λ_n: independent variable coefficient estimates

[Age]: age of fisherman as a continuous independent variable

[income]: stated income as an ordinal independent variable

[travel]: stated distance traveled to the most frequented fishing spot as an ordinal independent variable.

[employment]: stated employment status as a categorical independent variable

[recreational use]: stated recreational use after the implementation of MPAs as an independent ordinal variable

[Gear type]: the stated gear type used as a categorical independent variable

[MPA]: stated previous use of areas designated as MPAs as an ordinal independent variable

The coefficients preceding λ_n in the model reflect each independent variables respective influence the willingness to pay for the lobster stamp. To first determine which dependent variables had a significant effect on the respondent's willingness to pay, a stepwise regression analysis was used to determine which factors or combination of factors were statistically significant to include in the regression equation. Using only the data that was statistically significant at the 95% confidence interval ($p<0.05$), the OLS regression was done to create a model indicating which independent variables from the data had an effect on the amount of support for a lobster stamp program.

C. OLS Regression on WTP for Yes Answers

The OLS regression analysis on the willingness to pay for responses that indicated support for the lobster stamp program was completed in the exact same manner as the previous regression analysis. However, the willingness to pay value that was associated with responses not in support of the lobster stamp program or a "no" responses were left out of the regression analysis. The following regression equation was predicted to reflect the factors solicited from the survey that affected an indicated willingness to pay:

$$WTP = \mu_0 + \mu_1[\#\ years\ fishing] + \mu_2[age] + \mu_3[income] + \mu_4[travel] + \mu_5[employment] + \mu_6[recreational\ use] + \mu_7[geartype] + \mu_8[MPA] + \varepsilon$$

Where:

[WTP]: willingness to pay value as the dependent continuous variable ("yes" responses)

μ_0: y-intercept of the model

μ_n: independent variable coefficient estimates

[Age]: age of fisherman as a continuous independent variable

[income]: stated income as an ordinal independent variable

[travel]: stated distance traveled to the most frequented fishing spot as an ordinal independent variable.

[employment]: stated employment status as a categorical independent variable

[recreational use]: stated recreational use after the implementation of MPAs as an independent ordinal variable

[Gear type]: stated gear type used as a categorical independent variable

[MPA]: stated previous use of areas designated as MPAs as an ordinal independent variable

V.4. Data-gathering and Analysis System and Methods

V.4.i. Survey Design

An exhaustive survey scoping process was implemented throughout its development up until the survey was submitted to targeted respondents. To begin the survey design process we referred to an intercept and mail-in survey conducted by the 1992 Nearshore Invertebrate Project and the CDFG, in conjunction with the California Seafood Council, CIC research, and Los Angeles/San Diego dive clubs. This intercept and mail-in survey was designed to gather information on the southern California spiny lobster recreational fishery (Haakar et al., 2003). Taking into account our client's needs, the structure of the previous CDFG intercept survey, the time allocated to this endeavor, and our project objectives, we decided to design our research questions so as to gather a broad dataset on different portions of the fishery.

We first drafted a paper survey (Appendix 1) and then created two additional survey methods based on the paper survey questions. We formed a postcard revealed-preference survey (Appendix 2), and implemented an online survey. The online survey was hosted by the United Pier and Shore Anglers of California (UPSAC), and is available at: http://www.lobstersurvey.org/ls-webapp/surveys/index.jsp. The paper survey (Appendix 1) gathered data on estimates of spiny lobster recreational harvest to evaluate present and past harvest of recreational fishermen. Towards that end, we solicited stated-preference harvest data from the current recreational lobster fishing season (2005/2006), the two previous seasons (2004/2005 and 2003/2004), and the average of all seasons prior to 2003/2004. A significant proportion of the survey was dedicated towards gathering qualitative and quantitative data on the fishing behavior of the regions' recreational lobster fishermen, and to gathering information on the socio-economic drivers (i.e. income, age, and employment status) of the fishery.

The survey also evaluated the potential support in the target region for a lobster stamp program. This section of the survey gathered data on how many people in our sample population were willing to pay for a lobster stamp program, and why or why not they support a stamp program. Essentially, this elicited a market value given by respondents reflecting how much they value the spiny lobster.

V.4.ii. Survey implementation

To access a representative regional population encompassing all regional fishing grounds, gear types and socio-economic characteristics, we divided our outreach efforts into three categories: in-person, direct contacts, and indirect contacts. Within each of these three categories we developed and tested various outreach methods, and further divided these methods by gear type (Table V-1). We then established survey implementation and outreach methods to reach all fishery participants (charter boats, dive clubs, dive shops, hoop-netter intercepts, and known fishery participants) in the most efficient manner.

Fisherman type	Where to reach them						
	In-person			Directly		Indirectly	
Scuba divers	Charter boats	Dive Clubs	Intercept	Email	Telephone	Online Survey	Dive shops
Free divers	Charter boats	Dive Clubs	Intercept	Email	Telephone	Online Survey	
Hoop-netters			Intercept	Email	Telephone	Online Survey	
Known fishery participants			Workplace	Email	Telephone		

Table V-1: Outreach Method Scheme

VI RESULTS

VI.1. Estimating Recreational Harvest

The total number of fishing licenses sold with ocean enhancement stamps in Santa Barbara and Ventura counties were used to estimate the number of fishery participants, which ranged from 8,917 and 19,425 (Figure VI-1) with a predicted mean of 6,109.

Current estimates of the size of the Santa Barbara and Ventura fisheries for *P. interruptus* had a range of 3,683 to 8,655 fishermen. These estimates have remained relatively constant over the study period (Figure VI-2).

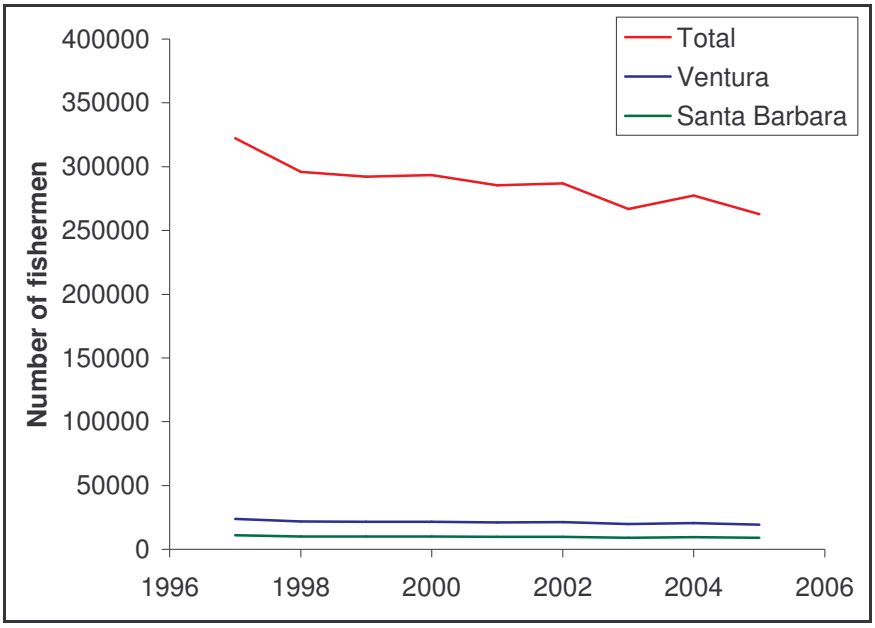

Figure VI-1: Recreational fishery particpants in Santa Barbara and Ventura counties (from RecFIN data)

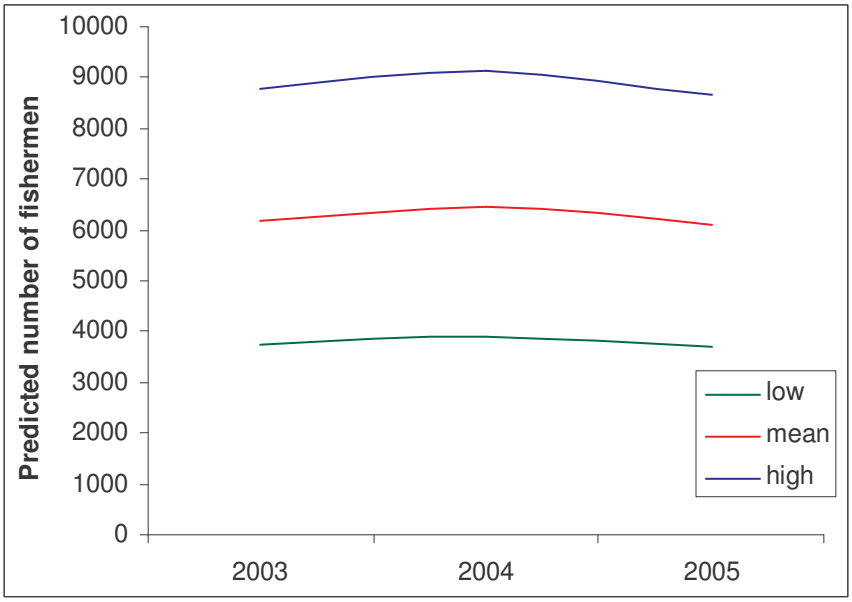

Figure VI-2: Estimates of fishery size for P. interruptus in Santa Barbara and Ventura counties

Fishing effort data compiled in the RecFIN database predicted estimates of participation for kelp bass and halibut recreational fisheries to be 28.9% and 31.9% respectively of the total (predicted) fishermen in 2005, and these ratios have remained relatively constant over time (Figure VI-3).

Data collected from Florida fisheries[1] for snook and Caribbean spiny lobster yielded similar results; the involvement in specific recreational fisheries ranged from 13% to 22% of total recreational fishing license sales (

Figure VI-4), For these four species, each specific recreational fishery represented 13% to 31.9% of total license sales. Therefore this range was adopted as a potential estimate of involvement in the recreational spiny lobster fishery in southern California.

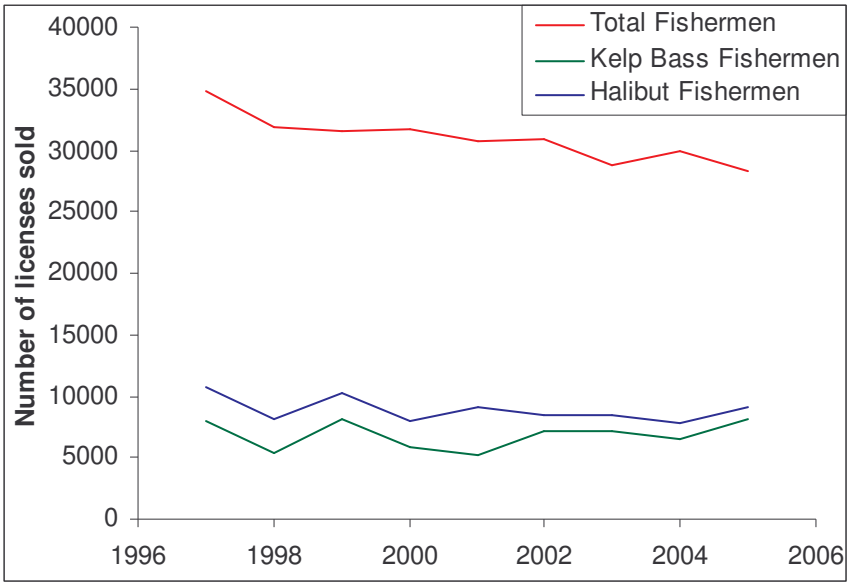

Figure VI-3: Involvement in kelp bass and halibut fisheries in Santa Barbara and Ventura

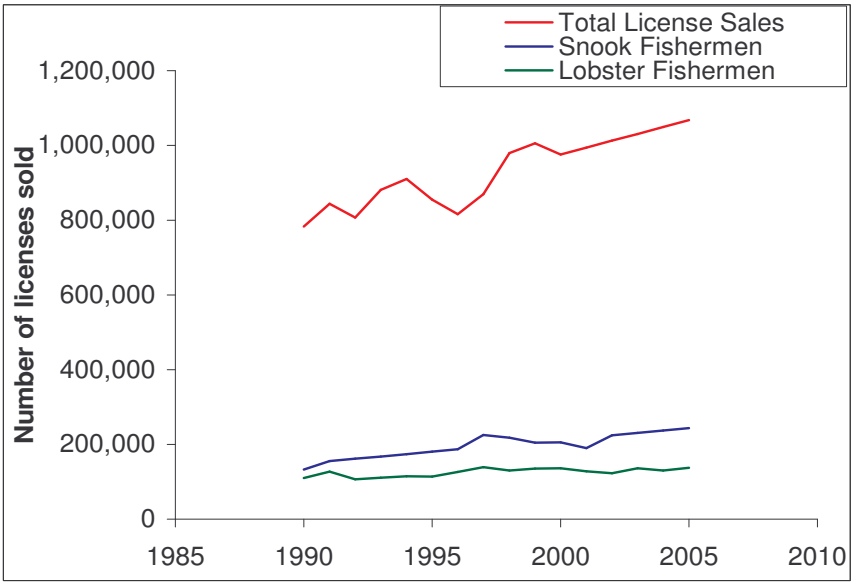

Figure VI-4: Involvement of snook and spiny lobster fisheries in Florida

[1] Fish and Wildlife Conservation Commission, St. Petersburg, Florida

Probabilities of observation followed a log-normal distribution across all gear types over the sampling time frame (Figure VI-5). The base model of recreational harvest was parameterized using these probabilities to infer the actual distribution of fishermen (Equation V.4). Correlations were evident between τ and e by gear type, therefore fishing efficiency could be estimated as a function of τ. Across all gear types, the relationship between fishing efficiency and the number of trips taken each season displayed a logarithmic relationship suggesting recreational fishermen choose to satisfy, rather than maximize *profits* (Figure VI-6).

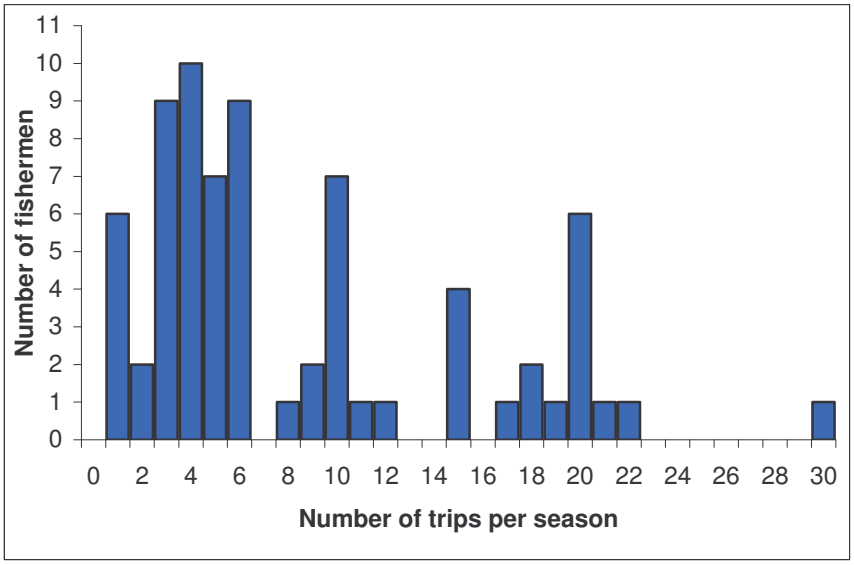

Figure VI-5: Distribution of τ across all gear types. See appendices for distributions of this parameter by gear type.

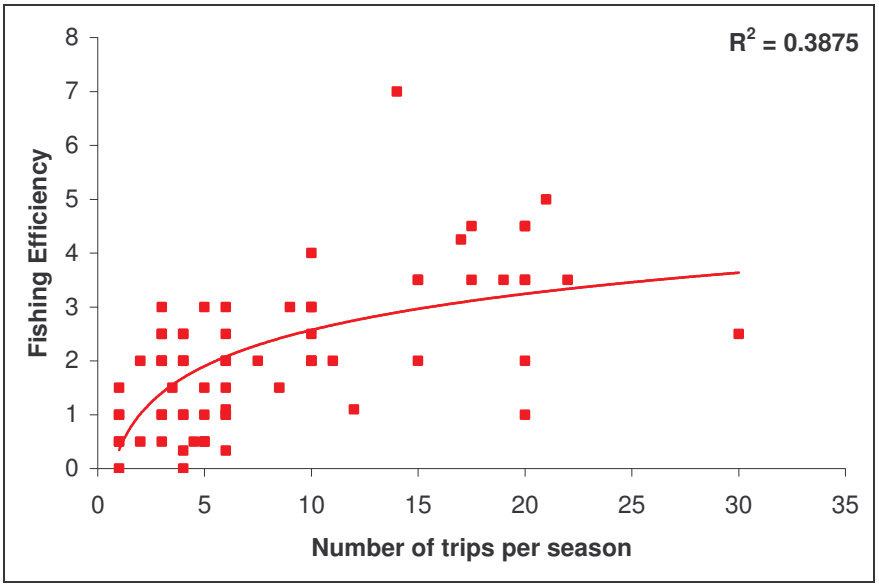

Figure VI-6: Correlation between fishing efficiency (e) and the number of trips taken each season (τ).

Over the range of estimates of f_{total}, recreational harvest varied from approximately 50,000 to 150,000 lobsters harvested during the 2004/2005 season (Figure VI-7). Scuba divers accounted for the majority of harvest (73.8%), with users of free diving gear and hoop-nets accounting for 16% and 10.2% of total harvest respectively. Temporal trends in harvest using the base model suggest little variance over time with respect to both total harvest (Figure VI-8) and harvest by gear type (Figure VI-9).

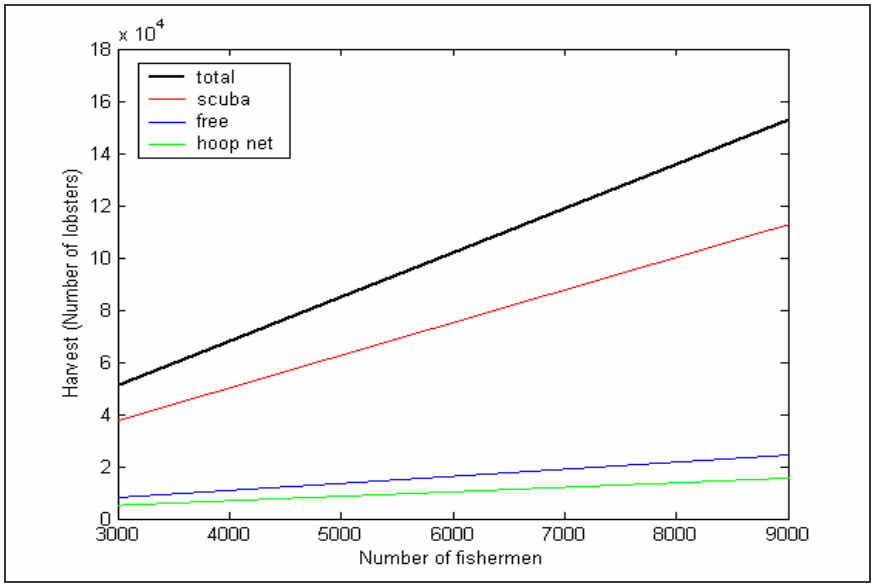

Figure VI-7: 2005 recreational harvest (H_{rec}) of P. interruptus by gear type using the base model

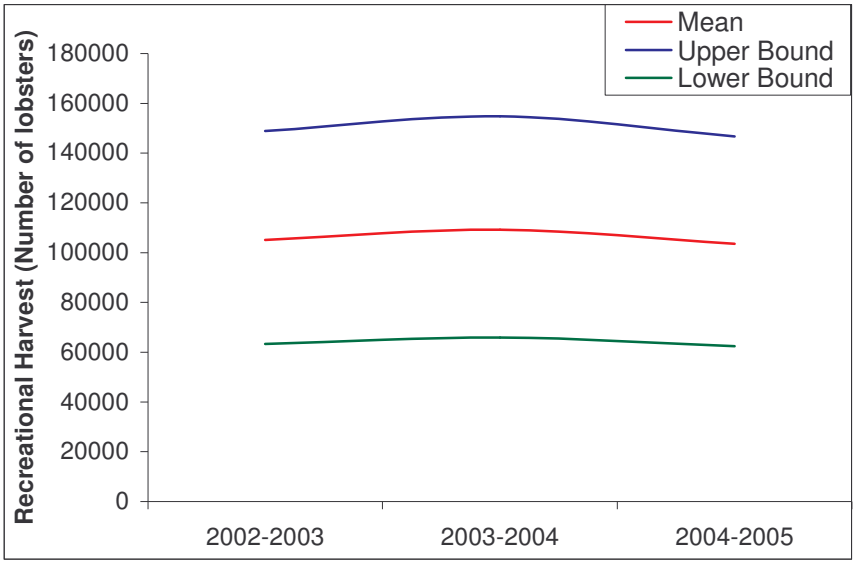

Figure VI-8: Temporal trend in upper, median, and lower estimates of recreational harvest

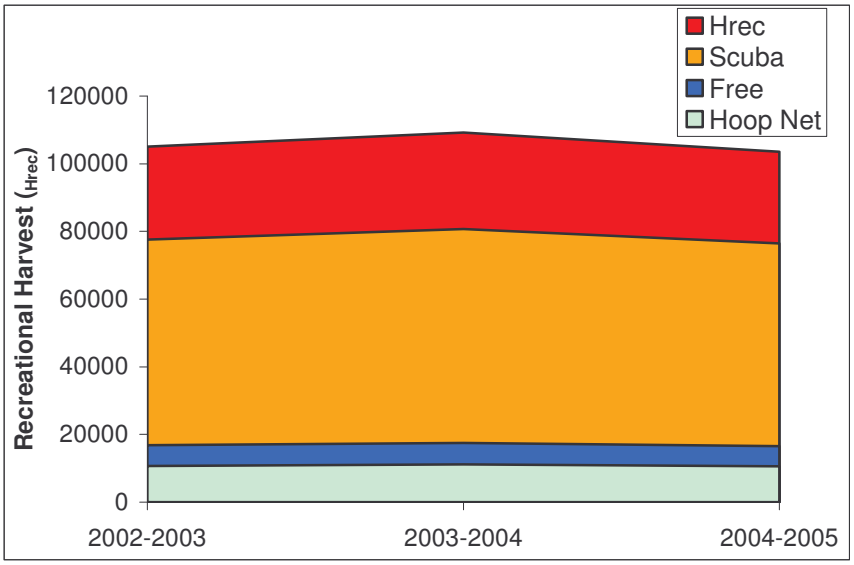

Figure VI-9: Temporal trend in harvest by gear type

Recreational harvest of *P. interruptus* may be compared alongside commercial harvest if commercial landings are converted from pounds to numbers caught. Although data on the mean size of commercially-harvested lobsters is not available, and accurate length-weight relationships are not available at present (M. Kay, *personal communication*), commercially harvested lobsters may typically range from approximately 1.6 to 2.4 pounds. Conversion of commercial landings (from CDFG final commercial landings records for 2003, 2004, and 2005) into lobsters harvested shows that the range in estimates of recreational harvest represents a significant proportion of total harvest, and is comparable to that of commercial fisheries (Figure VI-10).

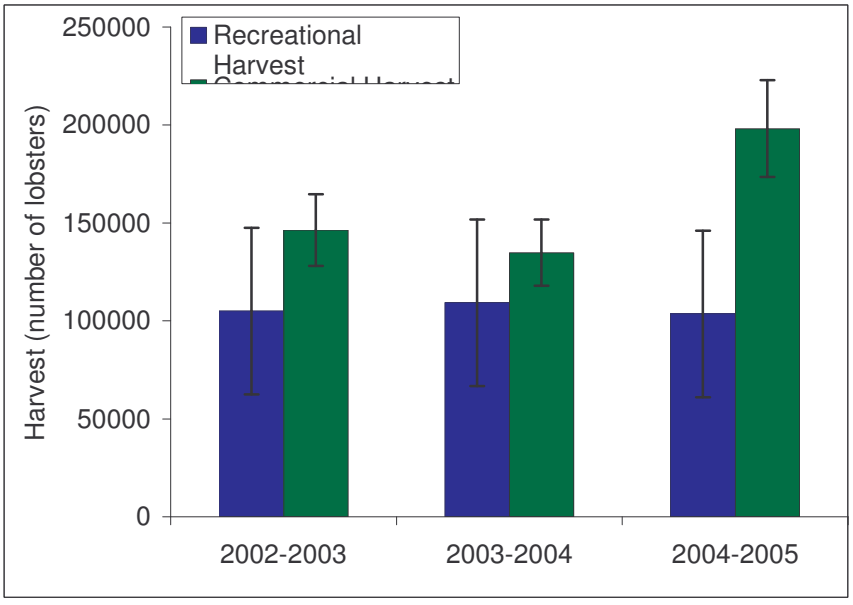

Figure VI-10: Comparison of commercial and estimated recreational harvest in Santa Barbara and Ventura counties.
Error bars reflect the range of harvest estimates for recreational harvest and adopted mean size of commercially harvested lobster ranging from 1.6 (upper limit) to 2.4 (lower limit) pounds

Integrating the effect of survey bias into estimates of recreational harvest resulted in a significant modification of the model's output. The Bias Index (BI) was determined to be approximately 2, 6 and 3 for scuba divers, free divers and hoop-net fishermen respectively. Over the range of estimates of f_{total}, recreational harvest varied from approximately 1,500 to 4,500 lobsters harvested during the 2004/2005 season (Figure VI-11), approximately one-third of the estimated harvest provided by the base model. Scuba divers again accounted for the majority of harvest (67%), however users of free diving gear accounted for approximately 29% of total harvest leaving hoop-net fishermen with only 4% of total harvest. Temporal trends in harvest using the model accounting for survey bias suggest some variance over time (Figure VI-12), however this variance is minimal when compared to variance in estimates of H_{rec} resulting from the range of potential estimates of f_{total}.

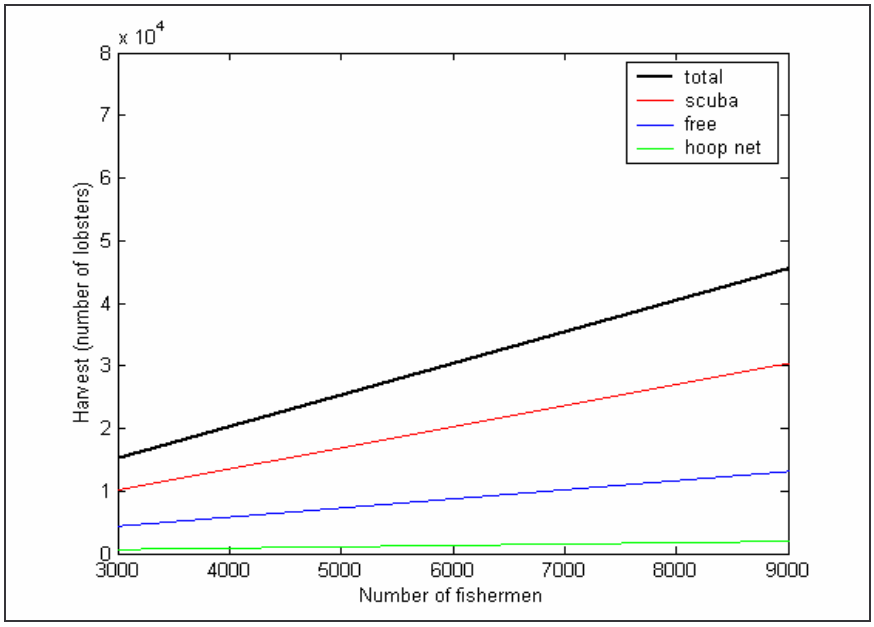

Figure VI-11: 2005 recreational harvest (H_{rec}) of P. interruptus by gear type accounting for potential bias in the survey tool

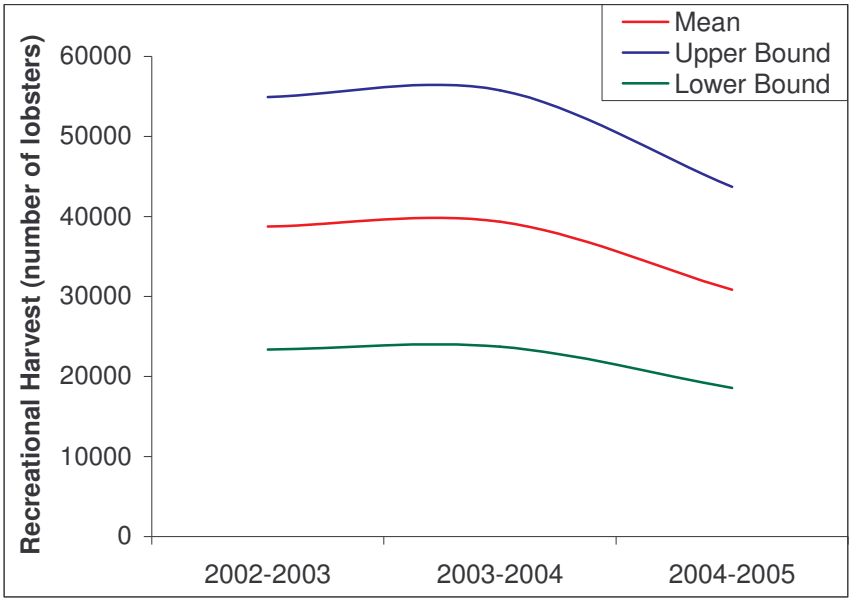

Figure VI-12: Temporal trend in upper, lower, and median estimates of recreational harvest

Temporal variance in harvest by gear type is minimal (Figure VI-13). However, harvest by hoop-net fishermen increases by 230% over the period of study (Figure VI-14).

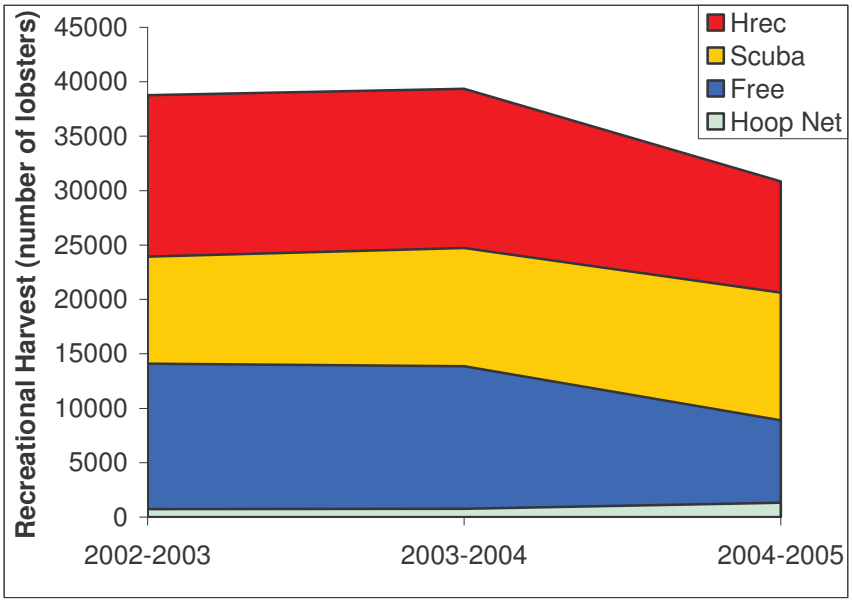

Figure VI-13: Temporal trend in harvest by gear type

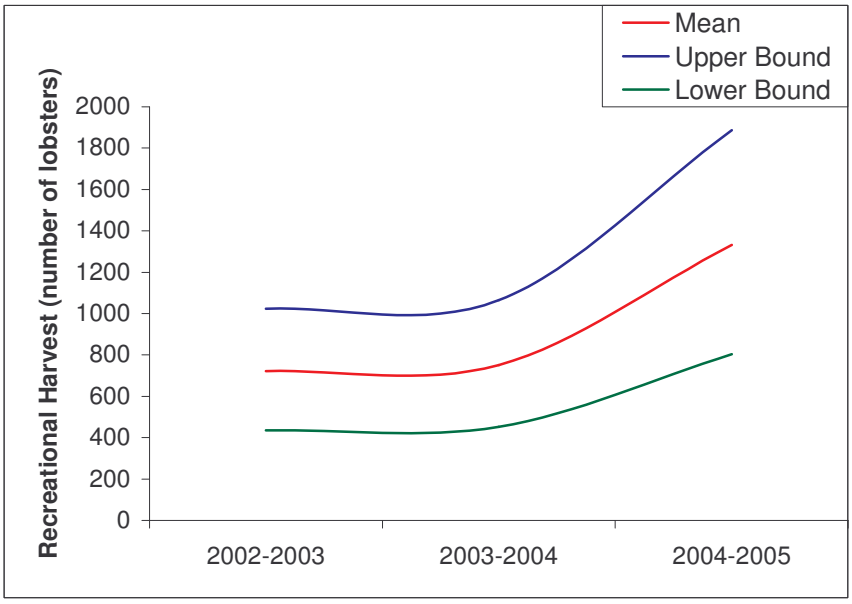

Figure VI-14: Predicted increase in harvest from hoop-net fishermen over the study period

Comparison of recreational harvest with respect to commercial landings using the modified harvest model accounting for potential survey bias presents results more comparable to the findings of Coleman (2004), with recreational harvest accounting for a maximum of approximately 30% of the total fishery for *P. interruptus* (Figure VI-15).

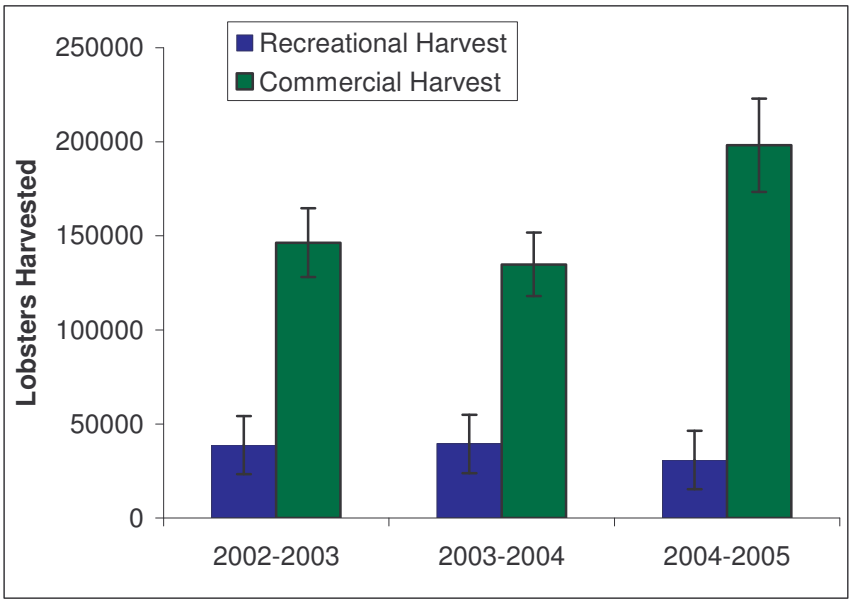

Figure VI-15: Comparison of commercial and estimated recreational harvest in Santa Barbara and Ventura using the recreational harvest model accounting for survey bias.
Error bars reflect the range of harvest estimates for recreational harvest and adopted mean size of commercially harvested lobster ranging from 1.6 (upper limit) to 2.4 (lower limit) pounds

VI.2. Fishery Socio-economic and Behavioral Dynamics

The summary statistics results presented below are based on the data collected from the stated-preference paper survey with using a total of 43 quality controlled respondents (N=43).

Question 1: The data gathered from the stated-preference survey Question 1 are summarized the Table VI-1 below. The results from the stated-preference survey indicate that the mean number of years fishing for all respondents was 10.88 years. In addition, 79% of the respondents had recreationally fished for lobster for more than 2 years. In other words, 79% of the respondents had fished prior to the establishment of MPAs. However, 21% of the respondents had fished for less than 2 years, or after the establishment of MPAs. In addition, we looked at a possible relationship between the number of years fished per fisherman, and the stated age category per fisherman. It appears that as the stated age of recreational fisherman increases for our sample population, the number of years fishing increases (Figure VI-16).

Table VI-1 Mean number of years fished for all respondents, and the percentage of respondents that have fished for lobster for more than 2 years and less than 2 years.

Average number of Years fishing	10.88
Fishermen who have fished for more than 2 years	79%
Fishermen who have fished for less than 2 years	21%

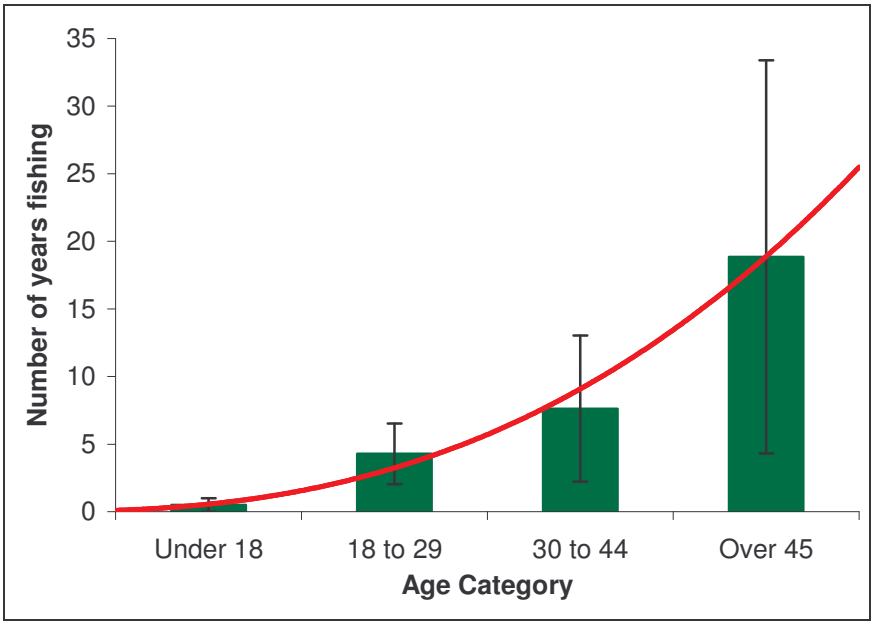

Figure VI-16 Relationship between a fisherman's age and the average number of years they have been fishing.

Question 2: The most common factor that determines where survey respondents fish, was "weather" (Figure VI-17). The second most common response was "the chance of finding lobster" or "word of mouth." The range of other answers that determine where respondents fished were: ocean swell, accessibility of sight, past performance, time availability, visibility, distance, kelp, bottom profile, boat availability, CDFG regulations. These percentage of each response with respect to the data set are summarized the graph below.

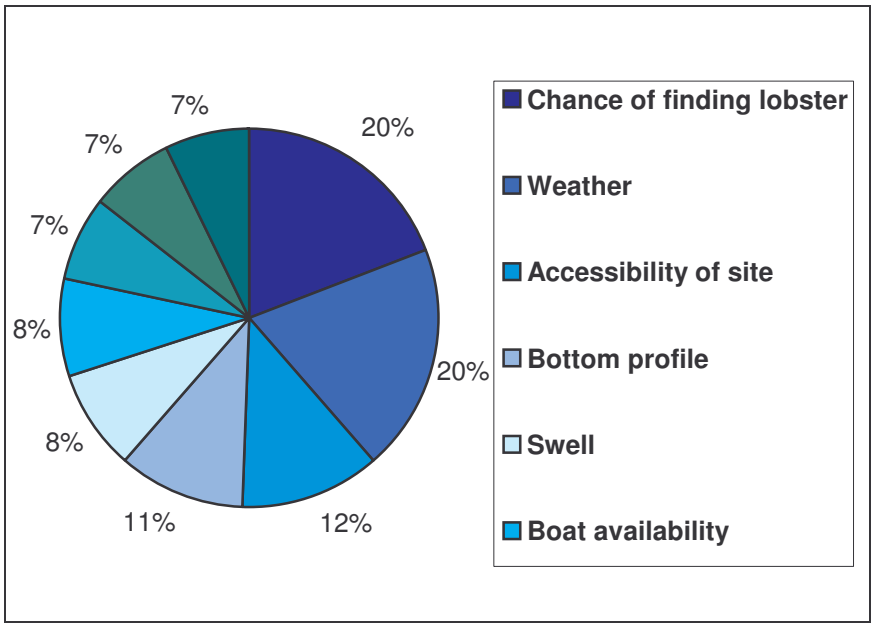

Figure VI-17: The factors that determine where survey respondents fish recreationally for spiny lobster as percentages of the total number of responses.

Question 3: The most common factor that determined why respondents fished for lobster recreationally was for "food" (Figure VI-18). The second most common reponse was for "sport." The range of reponses also included "leisure" and "exercise."

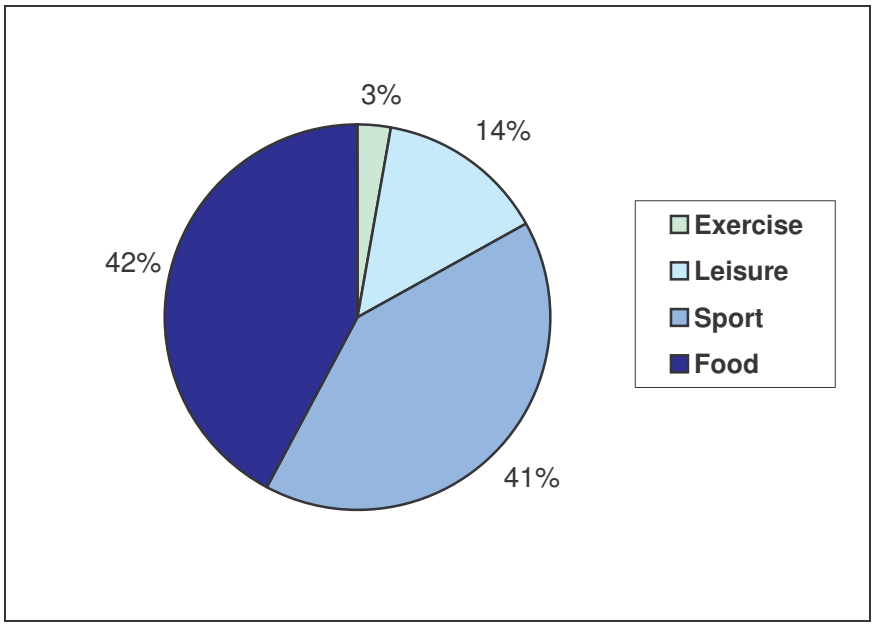

Figure VI-18: The factors that determine why survey respondents fish for lobster recreationally.

Question 4: 55% of the respondents stated that they did not previously fish in areas that are now designated MPAs. Of the respondents that previously fished in areas that are now MPAs (45%), the most previously frequented location was Anacapa Island, as stated by approximately 19% of the respondents. The second most frequented area was "Scorpion," which was indicated by 14% of the respondents. The other locations that were stated were: Richardson Rock, Judith Rock, Harris Point, South Point, Carrington Point, Skunk Point, and Gull Island.

Question 5: 74% of respondents indicated that the implementation of MPAs did not increase their recreational use, while 21% stated that MPAs did increase recreational use (Table VI-2). 5% did not answer.

Table VI-2: The percentage of respondents that stated an increase/decrease in Non-consumptive use due to the implementation of MPAs

Proportion of "NO"	74%
Proportion of "YES"	21%

Question 6: 50% of the respondents indicated that "enjoyment" was the most common factor that determined their choice of gear type. The second most common factor was "depth" which encompassed 17% of the responses (Figure VI-19). The range of additional responses includes: weather, ease of use, location, and money.

Question 7: 86% of the respondents indicated that they do not switch gear during any given fishing season, but 14 % of the respondents do switch gear during the recreational lobster season (Table VI-3). For 33% of the respondents that stated that they do switch gear, it was a result of the water depth in which they fish for lobster. The range of answers included: weather, enjoyment, chance of finding lobsters with a specific method.

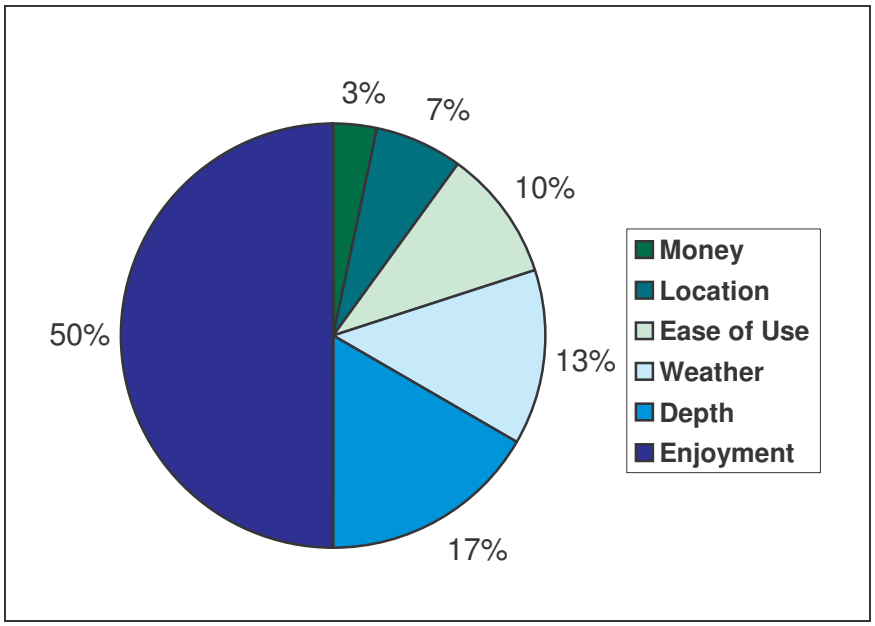

Figure VI-19: The factors that determine which gear type is preferred (reported in percentages) by the sample population of respondents.

Table VI-3 A summary of the percentage of respondents that do or do not switch fishing gear during any given recreational lobster fishing season.

Switching fishing gear	
Proportion of "NO"	86%
Proportion of "YES"	14%

Question 9: The respondents indicated that Weather/Visibility is the number one factor that determines the approximate number of trips taken per recreational lobster fishing season(Figure VI-20). The range of stated responses included: time, weather/visibility, money, and the chance of finding lobster.

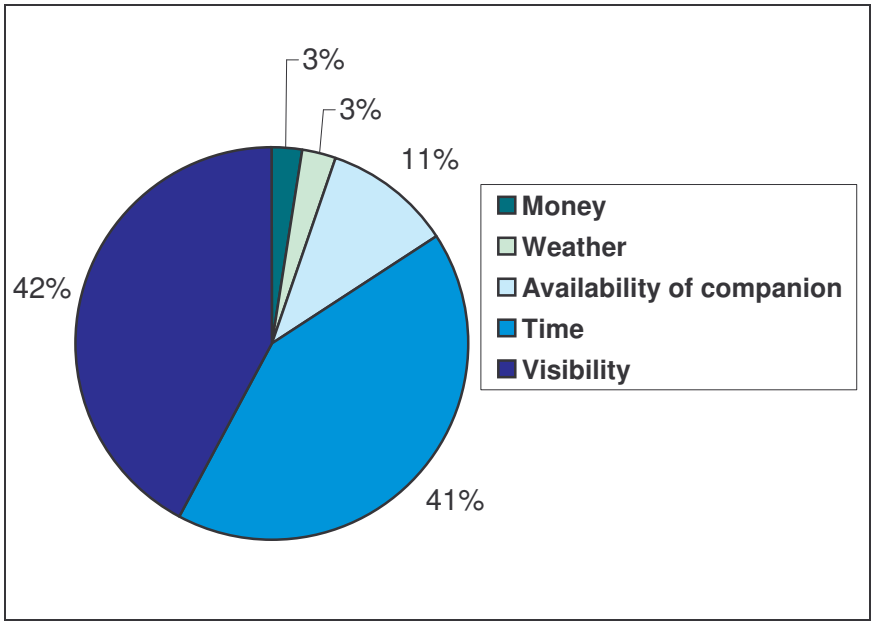

Figure VI-20: A percentage breakdowns of the most influential factors that determine the number trips taken per recreational season.

Question 13: Approximately 47% of respondents access the fishery using private boats, while 34% access the fishery from the shoreline. Only 16% of the participants access the fishery from charter boats, and a combined 3% of participants access the fishery from other unstated methods and from piers (Figure VI-21).

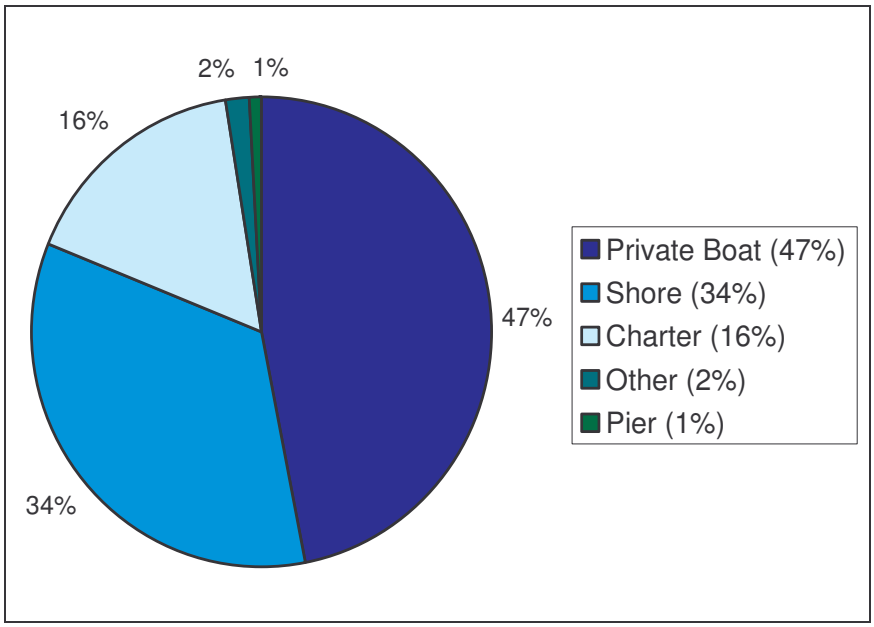

Figure VI-21: Indicates the percentage breakdown of the different methods by which respondents access the recreational Spiny Lobster Fishery.

Question 15: The results of Question 15 show that the majority (78%) of the respondents are within the age range of 30 to 59 years old. Only 5% of respondents were under the age of 18, and 17% of the respondents were in the age range of 18 and 29 years old (Figure VI-22).

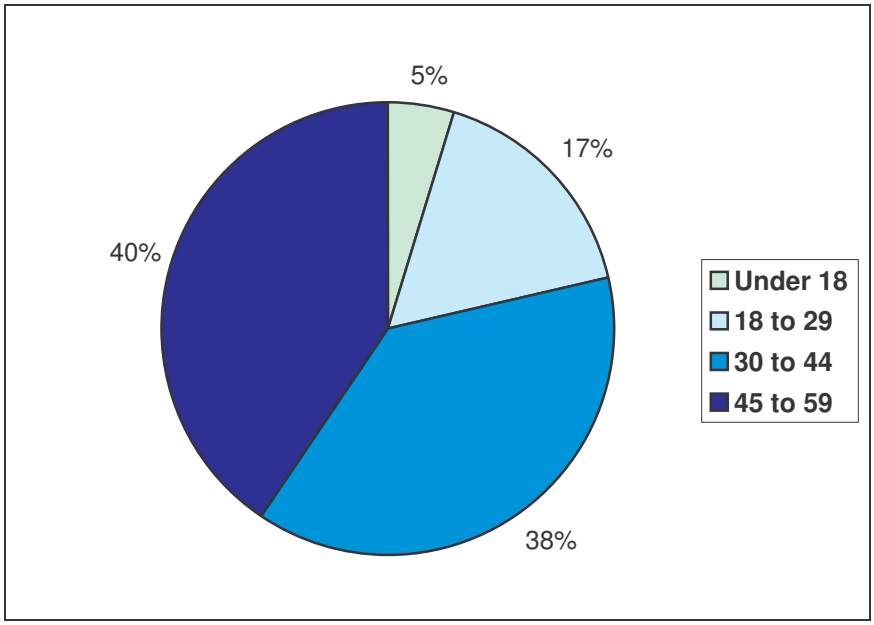

Figure VI-22: The percentage breakdown of age range categories stated by respondents.

Question 16: The majority of respondents stated that they were full-time employees (80%). The remaining respondents were spread evenly across the other categories of employment status, making up for 25% of the sample size (Figure VI-23**)**.

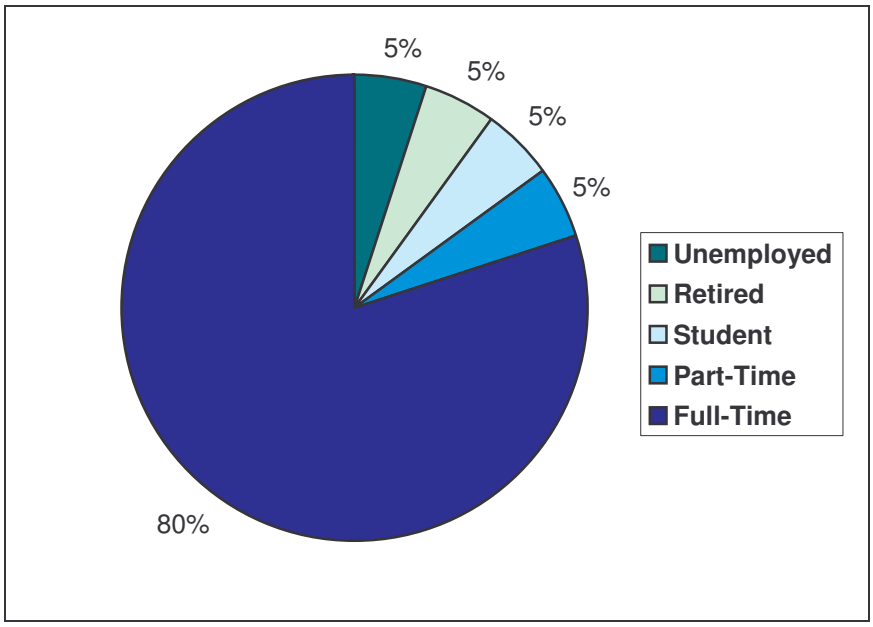

Figure VI-23: Percentage breakdowns of categories of employment status stated by respondents.

Question 17: 34% of respondents indicated that their individual income was over $80,000 per year. 42% of the respondents indicated they were in the categorical individual income range of $40,000 - $80,000 per year. Only 8% of respondents made below $20,000 a year and 16% between $20,001 - $40,000 a year (Figure VI-24).

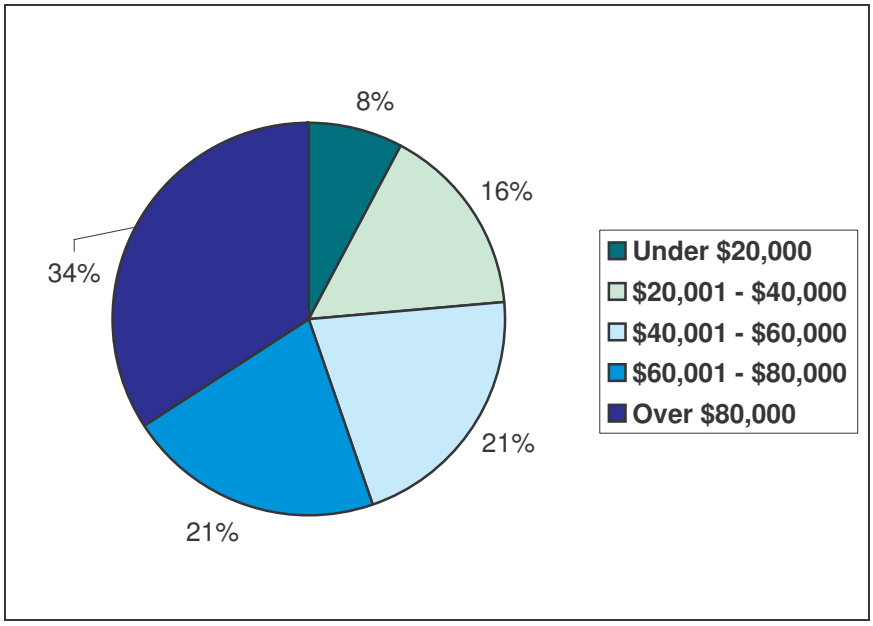

Figure VI-24: Percentage breakdown of individual income status stated by respondents

Question 18: 37% of respondents stated that they traveled less than 10 miles to their most frequented recreational fishing spot, excluding boat travel distance. An equal percentage of respondents, approximately 26%, either traveled between 11 to 20 miles or 21 to 30 miles to their most frequented fishing spot. 11% of the respondents traveled more than 31 miles to their most frequented fishing location (Figure VI-25).

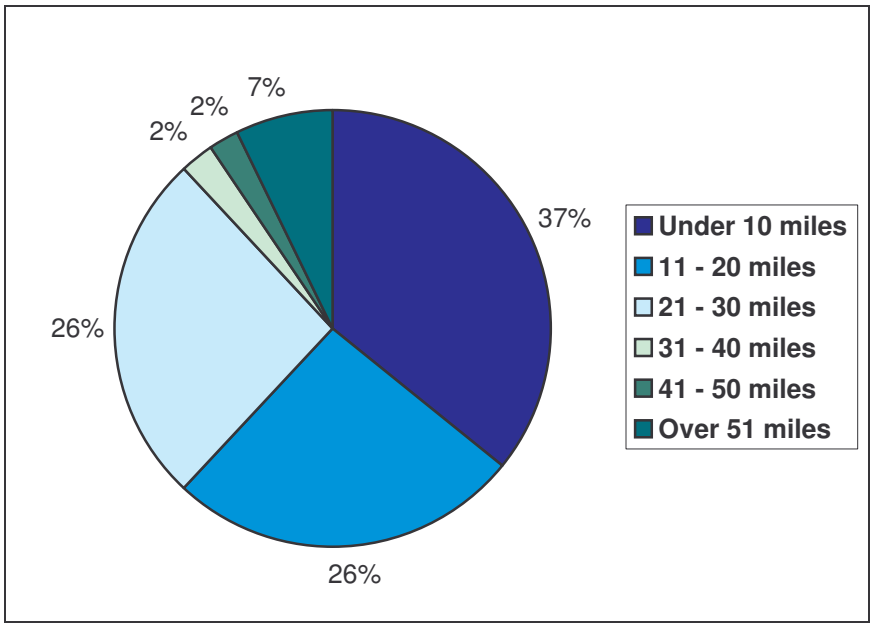

Figure VI-25 Percentage breakdown of the travel distance to most frequented fishing spot excluding boat travel distance.

Regression Analysis Results:

The relationship between the numbers of trips taken [# of trips] during the 2004-2005 and the previous use of MPAs [MPAs] was found to be the only significant regression relationship. The stepwise regression analysis on the number of trips showed that the independent variable [MPA] had a negative effect on the number of trips taken with a coefficient value of -2.99 at the 95% confidence interview (p=0.008) (Table VI-4). None of the other independent variables in the regression analysis showed a significant relationship with the number of trips, either at the 95% or 90% confidence interval. The regression analysis was based on the number of surveys n=42. For a summary of the assumption tests for the regression analysis see Appendix 3.

The logistic regression analysis that was completed for determining which factors affect the method of gear type used produced no significant results. This was a direct result of a sample that was biased towards one specific gear type (scuba). There was not enough resolution with respect to gear type in the data to find a significant relationship.

Table VI-4 The stepwise regression analysis indicates that the only independent variable affecting the number of trips is the [MPA] variable where p<0.008 and adjusted R^2 = 0.230.

Variable	Estimate	p-value	Variable	Estimate	p-value
Intercept	9.09	---	Number of years fishing	---	0.3
MPA	-2.99	0.008	Switch gear	---	0.4
Recreational Use	---	0.2	Income	---	0.8
Stamp support	---	0.6	Travel	---	0.7
Age	---	0.3	Willingness to pay	---	0.7
Employment status	---	0.9	$\#trips = -2.99[MPA] + 9.09$		Equation VI.1

VI.3. Lobster Stamp Program Support

Our investigation tested the level of support and willingness to pay for the lobster stamp program. The willingness to pay for a lobster stamp program can be directly used as a metric to gauge the fishery's level of support, quantifying the value assigned to the fishery by its participants. This in turn can be used by management agencies to calculate fishery-supported fees for a lobster stamp and to create an economically self-supporting program. The following results are based on our stated-preference paper survey, with a total number of forty-three (N=43).

VI.3.i. Lobster Stamp Support Summary Statistics:

To analyze the level of support for a lobster stamp program we first totaled and compared the number of "yes" and "no" responses from our survey. Out of a total of 43 respondents, 27 supported the implementation of a lobster stamp program, while 15 respondents did not. These results gave us fishery trends that indicate that approximately 64% of fishery participants support such a program, while 36% do not.

So as to further define the level of support for such a program, we gathered data on the reasons for and against support for the program. The responses to the open-ended question of "why or why not" respondents supported the stamp program were used to develop a percentage breakdown of the fishery's trends for or against support of the program (Figure VI-26).

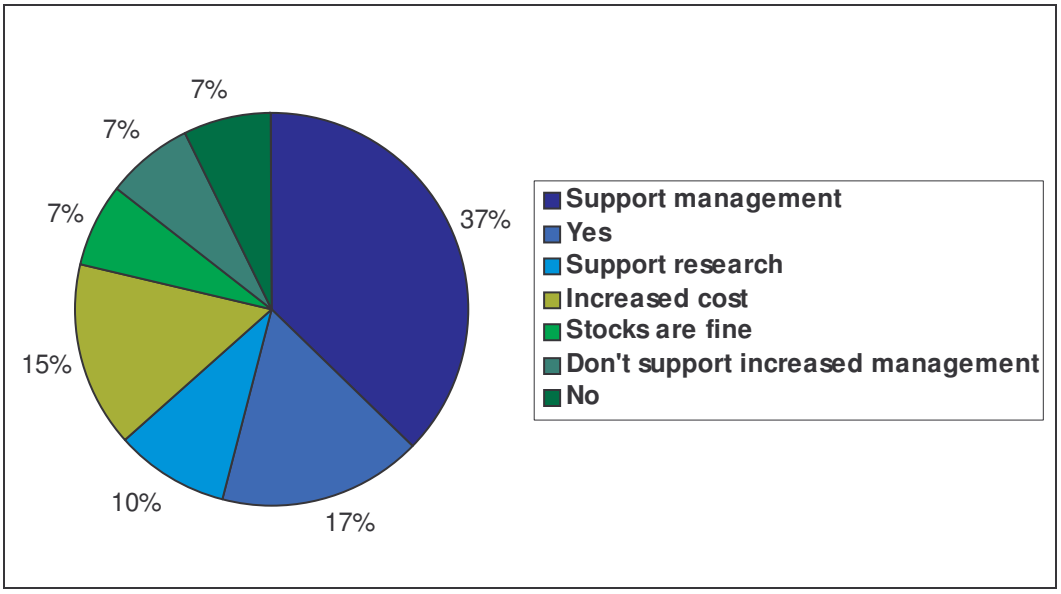

Figure VI-26: Rationales for support of the stamp
Blue: rational for supporting the stamp program
Green: rational for opposing the stamp program
"yes" and "no" alone represent the respondents that stated their position but did not give a rationale

The most common reason for supporting the lobster stamp program was because one supports management in general (37% or respondents), and the second because they support research (10%).

The most frequent reason for opposing the lobster stamp program was the associated increased cost (15%), followed by the notion that the stocks are fine and do not need more regulations (7%), and then the lack of support for increased management was noted for 7% of respondents.

To further substantiate the above results, the willingness to pay for the program was measured. The stated mean willingness to pay indicated by respondents for the lobster stamp program was $4.07 when including all responses (Table VI-5). All non-supporters were given a willingness to pay value of $0, and as such were influential in the reduction of the willingness to pay value for the entire fishery. The mean willingness to pay when only including those participants in support of the lobster stamp program had a value of $6.33 (Table VI-6).

Table VI-5 Willingness to pay for the stamp program when including all respondents
N = 43

WTP Summary Statistics (all)	
Mean	4.071
Standard Error	0.876
Median	2.000
Mode	0.000
Standard Deviation	5.676
Sample Variance	32.214
Kurtosis	2.370
Skewness	1.685
Range	20.000
Minimum	0.000
Maximum	20.000
Count	43.000

Table VI-6 Willingness to pay for the stamp program when including supporters only
N = 27

WTP Summary Statistics (yes)	
Mean	6.333
Standard Error	1.153
Median	5.000
Mode	5.000
Standard Deviation	5.994
Sample Variance	35.923
Kurtosis	0.923
Skewness	1.234
Range	20.000
Minimum	0.000
Maximum	20.000
Count	27.000

VI.3.ii. Regression Analysis:

A. Logistic Regression on Stamp with Dependent Variable as Nominal (Yes or No)

We ran a regression analysis on the position with respect to the stamp program. The model parameters that were tested are in the equation below:

$$Stamps = \gamma_0 + \gamma_1[\#\ years\ fishing] + \gamma_2[age] + \gamma_3[income] + \gamma_4[travel] + \gamma_5[employment] + \gamma_6[recreational\ use] + \gamma_7[geartype] + \gamma_8[MPA] + \varepsilon$$

However, the logistic regression analysis produced no significant results at the 95% confidence interval for estimates of λ; the tested independent variables (Age, # of fishing trips, # of years) did not have a significant effect on a respondent's choice to support the lobster stamp program (Table VI-7). In addition, an interaction term (# fishing trips*age) was incorporated into the model to assess the effect of age combined with the average number of fishing trips taken per season to determine if experienced recreational fisherman were more likely to support the lobster stamp program. There were no significant results recovered from the logistic regression analysis.

Table VI-7: Parameter estimates for the logistic regression analysis on support for the lobster stamp program. The shown p-values were found to be insignificant at the 95% confidence interval

Parameter	Estimate	Std. Error	p-value
Intercept	-5.048	2.765	0.0679
Age	1.787	0.982	0.0688
# fishing trips	-0.111	0.099	0.2666
# years fishing	-0.052	0.057	0.3696
(# fishing trips*age)	0.329	0.177	0.0635

B. OLS Regression on WTP as a Dependent Variable

A stepwise regression tool was used to assess which terms had a significant effect on the willingness to pay. The model tested consisted of the following equation:

$$WTP = \lambda_0 + \lambda_1[\#\ years\ \ fishing] + \lambda_2[age] + \lambda_3[income] + \lambda_4[travel] + \lambda_5[employment] + \lambda_6[recreational\ use] + \lambda_8[MPA] + \varepsilon$$ Equation VI.2

Of the tested parameter estimates, the [# of years fishing], [MPA], [age], [employment], [income], [travel], and [recreational use] were found to be significant at the 95% confidence interval ($p < .05$) (Table VI-8). The results of this analysis only included data from the respondents that supported the lobster stamp program. In other words, the calculations only included willingness to pay values for respondents that marked a "yes" in response to question 8 on the stated-preference survey. The same analysis was run including all respondents (supporters and non-supporters) but it yielded no significant results.

The ordinary least squares analysis showed that the number of years fishing had a negative effect on the stated willingness to pay (parameter estimate = -2.489). This indicated that, based on our survey sample, as the number of years fishing increases, lobster fishermen will be willing to pay less for a lobster stamp. A similar negative correlation was found with respect to age (parameter estimate = -19.300). However, the excessively high magnitude of this parameter estimate was unusual and may have been due to an unexplained variable that was not accounted for in the regression equation. Employment was found to have a negative impact on the willingness to pay (parameter estimate = -6.224), indicating that employed individuals are likely to pay less for a lobster stamp.

The MPA independent variable had a positive correlation of (parameter estimate = 1.300) with the willingness to pay, which could mean that the respondents that previously fished in protected areas are willing to pay more for a lobster stamp. Income was found to have a positive effect on a respondent's willingness to pay (parameter estimate = 5.101). Hence, fishermen with greater incomes are more likely to be willing to pay more for a lobster stamp. The travel distance to the most frequented fishing spot [travel] had a positive correlation with the willingness to pay (parameter estimate = 9.637). Therefore, the farther people travel to their most frequented fishing spot, the more likely they are willing to pay for a lobster stamp. The recreational use variable also indicated a positive correlation. This question attempted to solicit a respondent's increase or decrease in non-consumptive use in areas that were previously not MPAs after they were established as protected areas. It can be concluded that a stated increase in non-consumptive use with the establishment of MPAs was associated with a higher willingness to pay for a lobster stamp (parameter estimate = 8.567).

Table VI-8: Parameter estimates for the variables that were found to have a significant effect on the willingness to pay for the lobster stamp program at the 95% confide Nance interval ($p<0.05$).
The r-square value for the model was 0.8695, meaning that the model explains approximately 87% of the variability in the data.

Parameter	Estimate	F-ratio	P>F
# years fishing	-2.489	0.386	0.021
MPA	1.300	0.369	0.040
age	-19.300	10.485	0.018
employment	-6.224	8.329	0.015
income	5.101	5.121	0.064
travel	9.637	12.586	0.012
recreational use	8.567	7.421	0.035

VI.4. Data-gathering and Analysis System

To evaluate our survey implementation effort we created an evaluation scheme to assess the effectiveness of each outreach method. The evaluation scheme classifies each survey outreach method according its respective rate of return from respondents (Table VI-9).

The effectiveness of each survey outreach method was given a qualitative ranking according to its approximate rate of return from respondents. An effectiveness level of "High" warranted a 40% return of surveys from respondents. A 20% - 40% return from respondents was given an effectiveness level of "Medium", and any method that returned less than 20% of the surveys was given an effectiveness level of "Low."

Table VI-9. Efficiency of the outreach methods

	Outreach Method								
	In-person				Direct		Indirect		
	Charter boats	Dive Clubs	Intercept	Workplace	Email	Telephone	Charter boats	Dive shops	Online Survey
Effectiveness	High	High	Low	medium	Medium	Low	Low	Low	Low

The surveys that were implemented "In-person" were employed in three different categories of location: charter boats, dive clubs, intercept, and workplace. The stated-preference paper survey was given to respondents on the Truth Aquatic charter boat trip to Santa Cruz Island. There were 20 passengers on the boat, six of which were recreationally fishing for spiny lobster. There were six surveys returned, which yielded a 100% return rate from the fisherman that were given the survey. The two dive clubs, Paradise Dive Club and Ventura Dive Club, were allotted a high effectiveness level as they returned approximately 48% and 55% of the paper surveys respectively. The Paradise Dive Club has around 200 active members. We attended one of their monthly meetings where 50 members were present. 25 of the members were recreational lobster fisherman, and 12 surveys were completed and returned. Likewise, the Ventura Dive Club has approximately 300 active members, and we attended one of their monthly meetings where 40 members were present. 20 of the members present were recreational lobster fisherman, of which 12completed the survey. In addition, two other "In-person" survey outreach methods were employed (intercept and workplace). There were 3 attempts to intercept lobster fisherman at Ventura Harbor where hoop-netting is a common occurrence. Most of the fishermen that were met during intercept declared to not be lobster fishermen. There were no lobster fishermen present at Ventura Harbor during survey attempts, thus there were no returned surveys. However, there were 20 people that were directly contacted while at the workplace, and there were 5 surveys returned which gives a return rate of 25%.

Direct contact was done via two methods: e-mail and telephone. There were 43 e-mails sent to a combination of recreational lobster fisherman and recreational scuba divers. There were only 4 surveys returned using e-mail, hence the return rate for that outreach method was 9.3%. Six people were initially contacted over the phone. Of the six that were contacted, only one survey was directly brought to them in-person, which is a return rate of 16%.

The three indirect contact survey methods that were employed were leaving surveys with charter boat companies, dive shops, and creating an online version of the paper survey. Out of the primary contact list of charter boat companies, we worked with Truth Aquatics on survey outreach. 50 surveys were given to them for outreach purposes, and only 4 surveys were returned, which is a return rate of approximately 8%. We delivered 50 surveys to dive shops for outreach, and of the 50 surveys none were returned. The online survey, which was hosted by the United Pier and Shore Anglers of California (UPSAC), was completed by only 10 respondents, however is continually gathering data. UPSAC posted the survey link on their message board for their website, and the website receives approximately 1,500 hits per day.

VII DISCUSSION

VII.1.i. Estimating Recreational Harvest

Estimates of recreational harvest varied significantly over the range of predicted values of f_{total} and between the models used. Using the base model of recreational harvest, estimates of harvest had the potential to equate estimates of commercial harvest (H_{com}), and may have even exceeded H_{com} over the course of the 2003/2004 season. Since commercial landings in Santa Barbara and Ventura counties (and all of southern California) were some the highest on record, the range in estimates of total harvest from recreational fisheries were far below that of commercial landings. Over the time period investigated, recreational harvest was predicted to account for approximately 20% to 61% of total harvest (Figure VII-1). Recent estimates of the impact of United States recreational fisheries among populations of concern (such as bocaccio, *Sebastes paucispinus*) account recreational landings at 23% of total landings; however this figure rises to 38% in the South Atlantic and 64% in the Gulf of Mexico (Coleman et al, 2004). Coleman et al. speculate that this figure is reduced to only 4% when all compared to all marine fish landed, 10% when large industrial fisheries are excluded. Commercial fisheries for *P. interruptus* represent the third most valuable fishery in the Santa Barbara Channel region; therefore it is likely that estimates of the impact of recreational lobster fisheries are overestimated by the base harvest model. This is a reasonable assumption since the base model is quantitatively biased toward fishermen taking a greater number of trips each season, thereby overestimating rates of harvest.

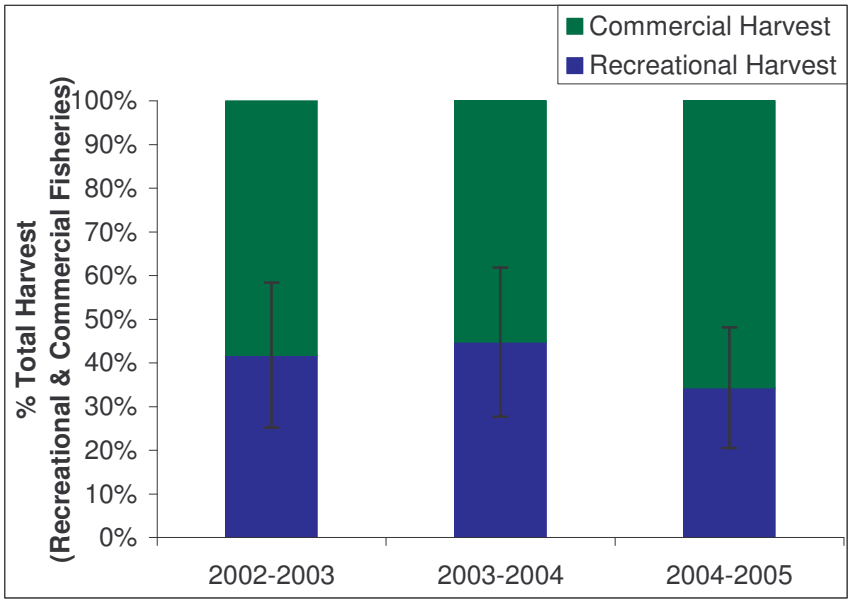

Figure VII-1: The impact of recreational fisheries for P. interruptus in the Santa Barbara and Ventura region (base model). Commercial harvest assumes a mean size landed of 1.6 pounds

Incorporating the potential survey bias into the recreational harvest model significantly reduces estimates of the impact of recreational fisheries (Figure VII-2). Over the time period investigated, recreational harvest was predicted to account for approximately 8% to 22% of total landings of *P. interruptus* when bias was considered. These results are consistent with the results presented by Coleman et al. (2004). Actual rates of the impact of recreational fisheries for *P. interruptus* in the Santa Barbara and Ventura regions will likely fall within the range presented in both models (~8% - 61% of total landings), however sampling remains warranted at a finer resolution. Using the model and incorporating bias as current best estimates of recreational harvest, the impact of recreational fisheries is potentially significant and deserves attention from management.

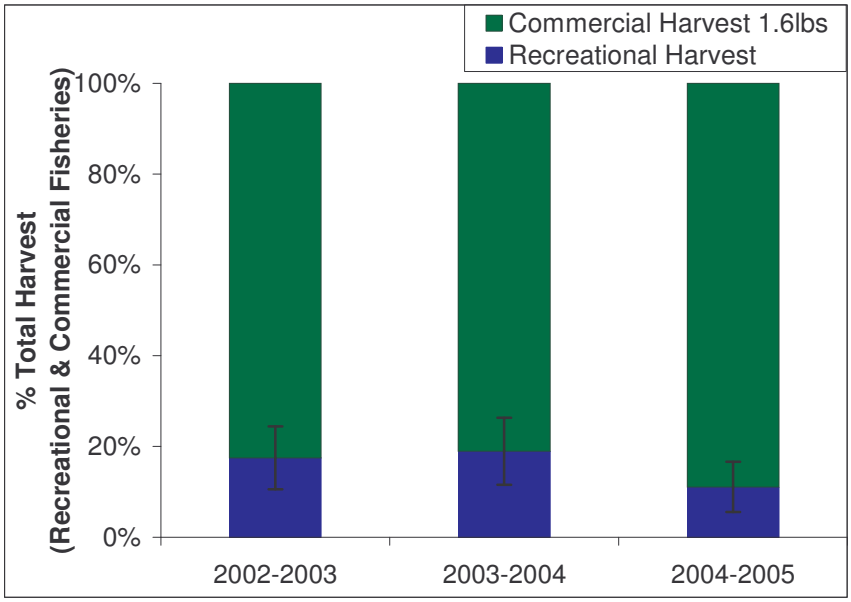

Figure VII-2: The impact of recreational fisheries for P. interruptus in the Santa Barbara and Ventura region (bias incorporated model). Commercial harvest assumes a mean size landed of 1.6 pounds

Commercial and recreational fishing have similar ecological and demographic effects on populations, abbreviating size and cohort structures while reducing total biomass. Recreational harvest of *P. interruptus*, depending on its intensity, has the potential to decrease the abundance of legal-size lobsters and the overall fecundity of mature lobster populations. When combined with commercial fishing, the likelihood of population-level changes may be manifested by decreasing mean size, abundance, biomass, and fecundity (Iacchei et al., 2005).

A better understanding of the ecosystem effects of recreational fishing is generated by a) a greater understanding of the direct impacts of fishing on populations, and b) increased resolution in estimates of the spatial and temporal intensity of harvest. Recent work (i.e. Iacchei et al., 2005; Castaneda-Fernandez et al, 2005; Pauley, 1998) has effectively quantified the patterns and processes resulting from commercial and recreational fishing. The results of this investigation suggest that estimates of recreational harvest may be derived using independent data-gathering and analysis systems. The use of a general, stated-preference survey allowed for data-gathering at a course-scale, generating estimates of harvest pertaining to a diversified sample of recreational fishermen. Subsequent investigations may now choose to focus efforts toward:

- The spatial structure of harvest. Are specific regions subject to directed fishing efforts, or is the spatial structure of harvest random? Since harvest is likely directed to preferred fishing grounds (as presented by our preliminary analysis), what is the distribution of fishing effort by area.
- Increased resolution in the dynamics of harvest by gear type. The survey tool used in this investigation was inherently biased toward scuba divers, as established groups of free divers and hoop-net fishermen do not exist. Correction of this bias may greatly influence predicted rates of harvest.
- Revealed-preference methods. Revealed-preference surveys offer finer data resolution than the stated-preference methods utilized in this investigation (Azevedo et al., 2003).

- Temporally replicated data-gathering and analysis systems. Increased temporal resolution offers the potential for analysis of trends in recreation harvest and the drivers of harvest.

A greater understanding of the extent of recreational harvest and the dynamic drivers of these fisheries will move scientists closer to an understanding of the ecosystem effects of recreational fishing, and move management agencies closer to an ecosystem-based management framework (Hall & Mainprize, 2004). If the goal of fishery management is the sustainability of fisheries, then both recreational and commercial fishing pressures must be quantified and the ecosystem effects of this harvest must be understood.

VII.1.ii. Fishery Socio-economic and Behavioral Dynamics

A. Socio-economic Profile of the Fishery

Due to the sample bias towards scuba divers, the socio-economic profile mostly applies to this gear type category.

The age distribution of fishermen corresponds to our expectations. We did not target respondents under 18 years old, unless a legal guardian was present to authorize us. Therefore we did not expect a high percentage of respondents under 18. Above 18, we expected a sample population with the majority of the respondents in the middle-aged categories (30 to 60 years old), because this is representative of the current population demographics. The age distribution in our sample follows the same shape as the age distribution in Santa Barbara and Ventura counties, but has higher percentages for the age categories 30-60 (Figure VII-3).

The employment status and annual income among our survey respondents is what we expected. Taking into account that most respondents are scuba divers and that diving gear and boat trips are more expensive than free diving gear or hoop-nets, we expected a population of employed people with incomes above average. The proportion of employed people from our survey respondents (85%) is higher than the county proportions in Santa Barbara County (58%) and Ventura County (62%; U.S. Census Bureau, 2000).

In addition, the annual per capita income of 76% of the respondents is higher than the Santa Barbara County average ($23,059) or Ventura County average ($24,600; U.S. Census Bureau, 2000). We expected that the average income would be high relative to the rest of the state, because Santa Barbara county and Ventura county are economically well-off counties. Our results show that the income is not only high relative to the state but also relative to this region. According to our results, lobster fishermen tend to have higher incomes than the county average.

Responses for travel distance were also close to our expectations. We expected that most fishermen would tend to live close to their fishing location, and 63% of the respondents travel less than 20 miles to go fishing. Travel distance can be a good indicator of the target population for some survey methods such as mailing surveys or door-to-door surveys.

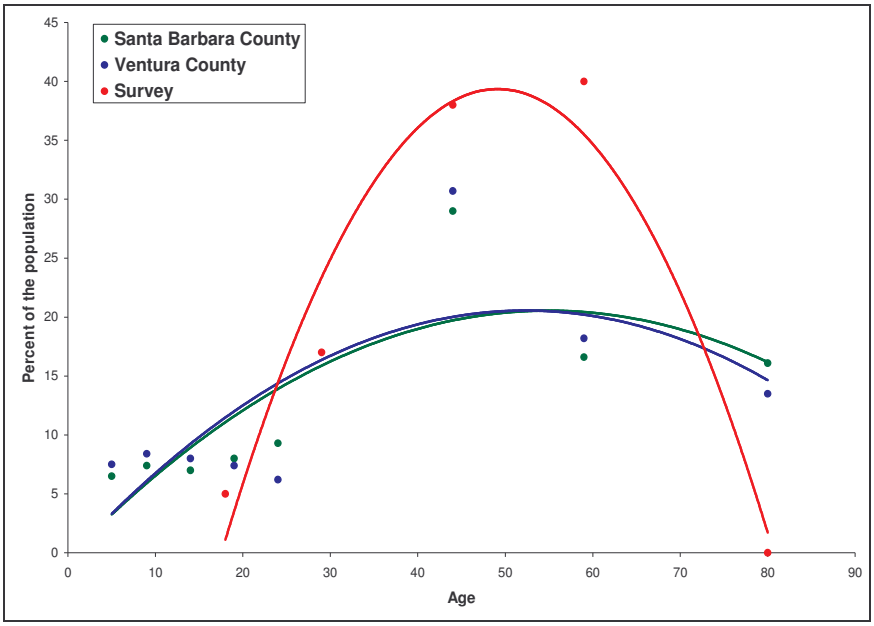

Figure VII-3: Age distribution from survey respondents compared to the age distribution in Santa Barbara County and Ventura County
(Data from the U.S. Census Bureau 2000)

B. Fishery Behavioral Description

Most of the respondents to the survey have been fishing for more than two years, so they used to fish before the implementation of Marine Protected Areas. The mean number of years fishing among the respondents is over 10 years. This indicates that there are many fishermen in the fishery that have accumulated experience and knowledge for a number of years. They could provide crucial information about trends in the fishery. Any management plan should therefore be developed in coordination with the fishermen.

Also, age and number of years fishing are positively correlated. This could be a result of the fact that most fishermen do not suddenly stop fishing. People enter the fishery at various ages but they do not leave it; it appears that the retention in the fishery is pretty high. One of the consequences of this is that the fishery does not have large fluctuations in size nor is cyclical. Based on this we can assume that the fishery will remain fairly stable in the future and therefore needs to be managed or monitored to assess its impact over time.

The factors that affect where people go fishing are what we expected. When fishermen decide to go fishing, they want to make sure that they have more chances to catch some. There is an opportunity cost associated with taking the time to go on a boat to go fishing and not catch anything. Therefore local “word of mouth” knowledge of where the lobsters are found will increase the chances of catching lobsters. Past performance is one indicator of lobster availability. Fishermen also want to make sure that the weather will be favorable and that the site is easily accessible to them so that they can fish in the best possible conditions. Conditions can also be defined by visibility, swell and bottom profile of the site. Furthermore, a lot of fishermen use charter boats. Charter boats tend to delay their trips or change their destination based on weather or sea conditions, so that would also affect a fisherman’s fishing spot.

The factors that affect why people go fishing were certainly biased because they were prompted in the question. The most common answer was “food”. However, this did not mean food as a mean of subsistence but rather as a statement that most fishermen like to eat lobster that they caught

rather than in a restaurant. This would suggest that fishermen would not be indifferent to releasing one after catching it as has been suggested by some. In addition, recreational lobster fishermen are allowed a bag limit of 7 lobsters, which makes the cost of each lobster higher than the open market price. Since recreational fishermen are not allowed to sell their catch, they will most likely keep the lobsters for food. The second most common answer was “sport”, which makes sense given the fact that a large portion of our respondents were members of dive clubs, whose focus is more on the sport of diving than on fishing.

Most respondents stated that they did not use to fish in MPAs prior to their implementation. However, the answers to this question should be looked at with caution. As any question referring to MPAs have management implications, it is likely that answers have been either overstated or understated.

The Northeastern side of Anacapa was designated as an MPA and was previously a recreational fishing area that was accessible to scuba divers. Scorpion is on the northeast side of Santa Cruz Island. It was previously a recreational lobster fishing area that was accessible to scuba divers as well. It should be noted that Anacapa and Santa Cruz Islands still represent the most fished areas in the region. This tends to indicate that fishermen did not relocate entirely after the MPAs were implemented; they continue to go to the same islands that they used to go. This could be due to the fact that the weather prevents trips to Santa Rosa and San Miguel more often than to Santa Cruz and Anacapa. Such could be supported by the fact that lobsters have been consistently larger in Santa Rosa than in Santa Cruz. Also, Santa Cruz is less harvested by commercial fishermen.

We expected that the implementation of MPAs would induce some non-consumptive use of the area. For example, scuba divers may still have dived in the MPAs but not fished for lobster anymore. Our survey revealed an opposite trend. However, due to the imprecise wording of the question and the target group that we approached, it is likely that the answers are biased. We expected that SCUBA divers would continue to dive in MPAs without catching lobsters, especially since they continue to go to the same islands. But the majority of “no” to the recreational use question indicates that fishermen will not continue to dive in areas where they cannot fish for lobster. They will not transfer the fishing part of their dives to another non-consumptive activity, but rather will dive in fishing areas. This is even more surprising since they cite enjoyment as their first factor for choosing scuba diving.

We expected that cost would be the major factor influencing the choice of gear type, as scuba gear is very expensive while hoop-nets are relatively cheap. However, our survey revealed that people choose their gear type based on enjoyment and conditions rather than money. This can be related to the socio-economic profile of the fishery as most of the respondents are full-time employees and have an annual income of over $80,000. Within this population, money is not a scarce resource and therefore does not impact the choice of gear type as we thought.

Most of the respondents stated that they do not switch gear during the season. This is likely to be due to our sample bias as we interviewed specific groups based on gear type. For those who did, they switched because lobsters are in different water depths at different times of year and they are going specifically for lobsters.

The number of trips that fishermen take per season is dictated by time. This can be explained by the fact that the majority of the respondents are full-time employees and thus time is limited. Weather and visibility also affect the number of trips taken per season, as we expected. Also, under bad weather it is difficult to take a boat out to a fishing spot or to set a hoop-net. The implication of this is that further intercepts attempts can be maximized by focusing on good weather days, when more people go fishing. The third most common answer was availability of companions, which is likely to be due to a bias towards scuba divers in the respondents. Scuba divers are encouraged to dive with companions, especially during harsh conditions. Lobster is

thought to come out and forage during the evening hours, and scuba diving alone in the dark is associated with certain risks.

The access type is certainly influenced by the sample bias towards scuba divers, as the most common answers are scuba-specific. However, this information could be useful in the sense that it could indicate the best areas to target for intercepts surveys if it was gathered in a less biased way.

C. Regression Analysis

From our observations of the behavioral dynamics of the fishery, we designed two models based on a regression analysis. These models would allow making predictions with respect to the number of trips that fishermen would be likely to take or the gear type they would be likely to choose, given their socio-economic and fishing profile. The analysis did not turn out to be significant due to the low sample size and the strong bias towards one gear type. However, given a large enough sample size, we would expect that some of the parameters would turn out to be significant.

For example:

- We would expect that the number of trips would be positively correlated with age in the 18 – 60 year old range and then negatively correlated with age in the 60 and above age range, as our age distribution showed.
- We would also expect that the number of trips would be positively correlated with income, and negatively correlated with travel distance, due to the cost incurred by transportation, scuba gear and boat trips.
- In addition, we would expect that the number of trips would be higher for students, part-time workers and retired fishermen because they have more free time and some income. In addition, the number of trips would be lower for full-time employees because they have less time, and even lower for unemployed fishermen because of the cost.
- Similarly, we would expect that the number of trips would be higher for hoop-netters than for free divers and higher for free divers than for scuba divers because of the cost associated with scuba gear and boat rentals.
- Finally, we would expect that the number of trips would be higher for fishermen who used to fish in MPAs before, because if people used to take more trips, it is more likely that they used to go to more places, i.e. since the established MPAs.
- With respect to the gear type, we would expect that the 30 – 60 year old fishermen would favor scuba diving and free diving over hoop-nets, while fishermen under 30 or over 60 would favor hoop-nets, because they are cheaper and potentially easier to use.
- We would also expect that fishermen with higher income would tend to favor scuba diving over hoop-netting and free diving while fishermen with lower incomes would favor hoop-netting and free diving, which are much cheaper to use. Based on that, we expected that employed fishermen would favor scuba diving while students, retired and unemployed fishermen would favor free diving or hoop-netting.
- Lastly, we would expect that scuba divers would be more likely to have fished in a MPA before since MPAs are only reached through boats.

VII.1.iii. Lobster Stamp Program

Our findings show a significant trend in the fishery's support for a lobster stamp program. Due to our small survey respondent size and the possible bias in our survey population, our results are used to create a preliminary description of the fishery's dynamics and drivers, and to help refine our data-gathering and analysis system. Yet the fishery's preliminary socio-economic and

behavioral description (see Results) may also be used as a metric against which to assess and help explain the fishery's support for the lobster stamp program.

We thus use the results to verify and elucidate both the fishery's support for the stamp program and it's willingness to pay for it. A comparison analysis of stamp support and socio-economic profiles of fishery participants and the fishery's behavioral dynamics presents many correlations between these data points, and helps to clarify the fishery dynamics behind the support of this program. For instance, a possible skew in the behavioral dynamics of the portion of respondents that support a stamp is clearly evident in the proportion of non-stamp supporters and fishermen most against regulation. This can be observed by aggregating fishery participants who were against the implementation of MPA's and those who were against filling out a survey (prior to being convinced to voice their opinion and non-support through completing a survey) for fear of increased regulations, and comparing this aggregated population against the ratios of stamp supporters and non-supporters. Such a comparison creates two distinctively clear respondent sub-populations of regulation supporters and regulation non-supporters, and demonstrates one of the possible relationships between stamp supporters and regulation supporters. Another such correlation can be seen in a comparison of the fishery's age structure and the portion of the population that supports the stamp program shows that there is an inverse relationship between age and the level of support; young fishermen are more likely to support the stamp program.

Further analysis comparing the socio-economic and behavioral parameters of the fishery and its willingness to pay for the stamp program gives us the following findings. A comparison of the abovementioned respondent sub-groups and their willingness to pay for the stamp demonstrates that those respondents in favor of regulations, i.e. in favor of MPA's and those who claim increased non-consumptive use of the Channel Islands National Marine Sanctuary, are more willing to pay for such a program. A comparison of the fishery's age structure and the portion of the population that is willing to pay for the stamp also shows an inverse relationship between age and the level of support and willingness to pay; young fishermen are more likely to pay for the stamp. Similar comparisons show that newer fishery participants are more likely to pay for the stamp, as are participants with a higher income, and those with longer travel distances to their fishing destination. These are self-evident findings in that participants with more disposable income are less likely to be burden by the cost of a stamp program, while participants that must travel significant distances to access the fishery are more likely to support regulations aimed at the sustainability of the fishery.

These findings are based on the preliminary description of the fishery as derived from our investigation's data-gathering and analysis system. As such they represent an important tool for the continued investigation and description of the recreational spiny lobster fishery; supporting the implementation of a lobster stamp program and allowing for amendments and changes to be made to our data-gathering and analysis system such as the possible introduction of population specific survey methods. The analysis of our lobster stamp results suggests that our stated-preference survey method is a valid tool to measure the fishery's support for lobster conservation efforts, and should be replicated to ensure the validity of our findings. Prior to replication of the survey system, the lobster stamp support question should be rewritten to account for the bias found in our current results; namely bias associated with the method wording of the lobster stamp support question. Rewording the question will further validate future survey results by creating a clear and concise non-bias question.

Our investigation's lobster-stamp-support survey methods and findings have the capability to substantially influence the current understanding and management of the recreational spiny lobster fishery. The implementation of a lobster stamp program and the subsequent initiation of our data-gathering and analysis system and harvest models will allow management agencies, such as the CDFG, to move towards an ecosystem-based marine resource management system which considers all fishery impacts and benefits to the local biological and geopolitical environment.

VII.1.iv. Data-gathering and Analysis System

Expectantly, this investigation can be assembled into a practical fishery management tool for the CDFG, to serve as a foundation to further investigate and describe the recreational spiny lobster fishery. To this end, our investigation has created a graduated system of recommended action plans to further our findings, and the description and quantification of the California spiny lobster fishery. Due to the nature of our sampling methods, our sample population was strongly biased towards scuba divers. Hoop-netters were the least represented in the survey responses. Therefore, our findings are likely to apply more accurately to the scuba divers of the fishery and less to hoop-netters. Additionally, our sample population was chiefly representative of fishermen that were directly surveyed during dive club meetings. As such, we recognize that there may be a correlation between the likelihood that dive club members have been diving longer than most other survey participants. Therefore they may be more likely to have been fishing for lobster for a longer period of time since recreational lobster fishing is traditionally a scuba diving sport.

After compiling and analyzing the stated preference survey-generated data, we identified questions that contributed negligible data to the H_{rec} model, and to the fishery socio-economic and behavioral dynamic estimations. There was reluctance among the survey participants to complete the survey for fear of further management. General feedback from our sample population and focus group indicated that the survey was too long and overwhelming. Thus we decided to adjust the content by removing these questions.

In addition, our attempts to gather data through intercept surveys yielded a much lower return rate than we had anticipated. We attributed this to two factors. First, the timing of our outreach did not coincide with the peak of the lobster season, which occurs at the very beginning of the season within two months of the opening date. Secondly, intercept surveys are more time and resources consuming than the other methods. In conclusion, we found that in-person methods yielded a much greater rate of return than indirect methods. However, in-person surveying creates inherent bias do to a lack of randomness is sampling. Intercept surveys done in a systematic way might help to reduce the bias towards one or another type of fishermen, but they cause another type of bias; fishermen who take more trips per year have a greater chance of being intercepted. The data gathered through intercept surveys should be considered as biased towards higher τ.

VII.2. Recommendations

The data-gathering and analysis system was used to develop a fishery harvest model of which harvest rates and fishing effort were used to compliment insight into the fisheries socio-economic profile. In addition, we found that local support for the implementation of a lobster stamp program was warranted due to a positive response from fishery participants. Through continued improvements to the data-gathering and analysis system's surveys, models, and analysis methods, further resolution and insight into the fishery can be achieved. Continuing this investigation and implementing the data-gathering and analysis system on a broader scale under specific criteria, and supplementing it with the implementation of a lobster stamp program could provide a valuable management tool to serve as the foundation for an extensive fishery description.

VII.2.i. Implementation of Data-Gathering and Analysis System

We recommend that the CDFG implement the system to replicate the survey on a yearly basis, which would increase the accuracy of the profile each year through an increase number of respondents. This would also allow for observations of temporal trends within the fishery if each season's profile could be compared to previous seasons' profiles.

The only implementation scheme that would target every fisherman equally would be to employ the lobster stamp program and distribute the survey to every fisherman who buys it. This would allow targeting all three gear types without bias and fishermen who fish frequently as well as one-timers.

If other methods have to be used, we recommend the use of an online survey provided the use of some guidelines to limit the introduction of bias in the target population. The CDFG may want to set a more neutral website to host the survey. The online survey should be the same as the paper survey, and the output in the same format, to allow for aggregation of the data.

We also recommend the use of the paper stated-preference survey, to access the fishermen who do not have easy or regular internet access. Direct methods such as attending dive clubs and dive shops meetings or addressing known participants through e-mail, telephone or in-person at their working place can yield a large return rate but incur bias because the method is not random. Intercept surveys are more random but more time and resource consuming. In addition, they are the only way to get to hoop-netters. However, they yield a different type of bias in the sense that the fishermen who fish more are more likely to be sampled. This correlation issue can be addressed using the same probability equation we used for our analysis. With respect to the other type of bias, we recommend the use of the post-card survey to serve as a screening tool to randomize the survey implementation issue. The post-card survey could be distributed to all the fishermen but the paper survey only to every fifth person who fills out the post-card survey.

In addition, the post-card survey can also be used as a revealed-preference tool to target charter boat passengers, and get an estimate of harvest and of the proportion of lobster fishermen on each trip. Revealed-preference surveys provide more accurate information in the sense that respondents do not have the opportunity to over estimate or underestimate their harvest or frequency.

Overall, with respect to both stated and revealed-preference surveys, we recommend the implementation to be in-person and not indirectly. This survey method provides added resolution into the fishery by including hoop-netters, scuba divers, and free divers. In addition, these survey methods will capture participants that utilize different access methods into the fishery. Based on the previous recommendations, we have developed a graduated system of recommended action plans.

Recommended Action Plans:

PLAN A: Further test our lobster stamp findings by incorporating a stamp support question in their California Recreational Fishery Survey (CRFS) questionnaire. If results of this questionnaire also indicate the majority of respondents support a stamp program and improved management, the CDFG should then move to develop and initiate a stamp program that includes our survey and harvest estimate model as a means of monitoring the recreational fishery and generating revenue to be used for sole purpose of managing the lobster fishery.

PLAN B: If the lobster stamp support cannot be confirmed, then the CDFG should initiate our data-gathering and analysis system using the least bias methods (intercept and online surveys). This will allow for a more extensive description of the fishery than we conducted, and may foster further support for the lobster stamp program.

PLAN C: If Plan A or Plan B cannot be implemented, distribute the survey through the most cost-effective methods which include: distributing surveys at dive club meetings, dive shops, charter boats, and known fishery participants. This plan will further our investigation's preliminary description of the fishery, and may lead management agencies towards improved fishery management.

These methods will yield some bias which can be accounted for using bias-corrected calculations of f_t using revealed preference survey methods rather than stated preference surveys, or focusing on a particular attribute of the fishery such as the spatial structure of harvest, the socio-economic and behavioral drivers of the fishery, and/or increased resolution in the dynamics of harvest by gear type.

VII.2.ii. Implementation of Lobster Stamp Program

Support for the implementation of a lobster stamp program is substantiated by our findings and has the potential to significantly influence and improve the current understanding and management of the recreational spiny lobster fishery. But what exactly is a lobster stamp program? Is its implementation politically and economically feasible? And finally what steps can the CDFG take towards the creation, introduction and realization of such a program?

A lobster stamp program would be similar in scope and function to the CDFG's current ocean enhancement Stamp Program which is the revenue generating program for the Ocean Resources Enhancement and Hatchery Program (OREHP). "The OREHP began in 1982 with legislation (Assembly Bill 1414) authored by California Assemblyman Larry Stirling which funded the program's initial nine-year research effort" (UASC, 2005). The program requires the purchase and possession of an ocean enhancement stamp for all ocean fishing south of Point Arguello. All marine fishery participants, regardless of target species and except when fishing under authority of a one-day or two-day sport fishing license must purchase the annual stamp at the current cost of $3.95. The funds generated by the stamp program are earmarked solely for the OREHP program through Fish and Game Code Section 6595 (a) which states that "All fees collected by the department pursuant to this article, and any interest earned on those fees, shall be deposited in the Fish and Game Preservation Fund and shall be available, upon appropriation by the Legislature, solely for purposes of the program" (CDFG, Code 6595). In 2005 the CDFG sold 259,721 stamps generating $909,024 for the OREHP's stock enhancement efforts and biological and economic assessments of the fishery (CDFG, 2006).

As a direct result of the ocean enhancement stamp program, the CDFG is able to quantify annual recreational marine fishery participant totals and derive fishing effort towards a better understanding of fishery impacts on local marine species populations and an assessment of management efficacy. To further substantiate and supplement these annual statistics, the CDFG in collaboration with the Pacific States Management Fisheries Commission created the California Recreational Fisheries Survey (CRFS).

A lobster stamp program would further the findings of the CRFS and ocean enhancement stamp program by collecting fishery participant and effort data, allowing the CDFG to focus directly on the description and management of the recreational spiny lobster fishery. Prior to the CDFG's implementation of a lobster stamp program, further testing of the fishery's support and willingness to pay must be conducted. If the CDFG's analysis of these two variables (support and WTP) confirms our investigation's findings that such a program is indeed supported by the fishery and thus politically feasible, development of the program should revolve around a cost-benefit and willingness to pay analysis. Once implemented, the stamp program will provide data on annual fishery participant totals and could be complemented by our data-gathering and analysis system in the same manner that the ocean enhancement stamp is complimented by the CRFS. This would allow more comprehensive description of the fishery and could lead to better management and sustainability of the fishery.

Our investigations findings show that the lobster stamp program could indeed be economically feasible. Our investigation has derived recreational participant estimates ranging from 3,683 to 8,655 fishermen, with a predicted median of 6,109, for the Santa Barbara region. Lobster stamp support results indicate that 64% of the fishery supports the stamp, and that when we aggregate non-supporters with supporters, i.e. the entire fishery, and allocate a WTP of $0 for non-supporters and non-respondents, we find a total fishery WTP of $4. Using these findings we can estimate that a lobster stamp program would generate $4 per fisherman per year for a range of $14,732 to $34,620 depending on the actual size of the fishery. If we use the WTP derived from supporters ($7) in these same calculations then we get a range of $25,781 to $60,585. It must be noted that these potential revenues are only from the Santa Barbara Channel and northern Channel Islands

region and could be as much as tripled to account for the entire Southern California recreational fishery. Calculating these potential annual revenues tells us nothing of the stamps economic feasibility, but comparing them to the ocean enhancement stamp does. The ocean enhancement stamp in 2005 was selling at a price of $3.50, in 2006 the price was raised to $3.65 (CDFG, 2006), well below our potential price for the lobster stamp ($4 to $7). It can thus be inferred that if the ocean enhancement stamp is economically feasible in southern California, than so too would be the lobster stamp program.

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APPENDIX

Appendix 1: Survey

The Donald Bren School of Environmental Science and Management

This survey is aimed at collecting information regarding the socioeconomic drivers of the recreational spiny lobster fishery. It is the principal data-gathering component of our graduate school Master's research project. This investigation will highlight specific drivers of the fishery and the influence these drivers play on harvest. The goal of our research is to estimate the total recreational harvest of spiny lobsters in the Santa Barbara Channel and Channel Islands, in an effort to model the sustainability of the fishery. Thank you for your help. Please feel free to contact us with any questions or concerns at the following email address: *Spiny@bren.ucsb.edu*

DATE: [_____]

1. Please indicate the number of years you have been lobster fishing: [____]
2. What are the factors, or combination of factors, that determine where you fish?
   [_____]
3. What are the factors, or combination of factors, that determine why you fish (Food, Sport, Leisure, Other)?
   [_____]
4. Did you previously fish in any areas currently designated as marine protected areas? [_____]
   If so, where? [_____]
5. Has the establishment of marine protected areas increased your recreational use (Scuba Diving, Surfing, Sailing, etc.) of the Santa Barbara Channel and Channel Islands? [_____]
6. What are the factors, or combination of factors, that determine what particular gear type (Scuba, Skin-diving, or Hoop Net) you use to fish for spiny lobster?
   [_____]
   [_____]
7. Do you switch lobster fishing gear during a given season? [_] Yes [_] No
   If yes, why: [_____]
   when: [_____]
8. A Lobster Stamp Program consists of a minimal charge, in addition to the fishing license price, in exchange for a stamp that allows you to fish for lobster (similar to the ocean enhancement stamp). This would help quantify the number of recreational lobster fishermen, while funding work focused on ensuring a sustainable lobster fishery.

   Would you support the establishment of a lobster stamp program? [_] Yes [_] No
   Why / why not: [_____]
   If yes, how much would you be willing to pay: [_____]
9. Please rank the factors that influence the number of trips you take each season in order of importance (*1 = most important*):
   [_] Time [_] Weather/Visibility [_] Availability of companions [_] other _____

Please Indicate: ** If more than one applies, please indicate the percentage of your time devoted to each category*			For the current season (2005 / 2006)	For the previous season (2004 / 2005)	For the season of (2003 / 2004)	Average of all seasons prior to (2003)
10. Average number of lobster fishing **trips** you've taken **per season**						
11. Categories that best represent how you've taken lobsters*	Scuba diving		%	%	%	%
	Free diving		%	%	%	%
	Hoopnet		%	%	%	%
12. Average number of **lobsters** you've taken **per trip**	Scuba diving					
	Free diving					
	Hoopnet					
13. Categories that best represent the location from which you've fished for lobster*	Pier		%	%	%	%
	Shore		%	%	%	%
	Private boat		%	%	%	%
	Charter boat		%	%	%	%
	Other		%	%	%	%
14. Regions where you primarily fish spiny lobster*	Mainland Santa Barbara county		%	%	%	%
	Mainland Ventura county		%	%	%	%
	Northern Channel Islands	Santa Cruz Fronside	%	%	%	%
		Santa Cruz Backside	%	%	%	%
		Anacapa Frontside	%	%	%	%
		Anacapa Backside	%	%	%	%
		Santa Rosa Frontside	%	%	%	%
		Santa Rosa Backside	%	%	%	%
		Santa Barbara	%	%	%	%
		San Miguel	%	%	%	%

15. Please indicate your age:
    [_] Under 18 [_] 18 to 29 [_] 30 to 44 [_] 45 to 59 [_] 60 and over

16. Please indicate which category best describes your employment status:
    [_] Full Time [_] Part Time [_] Retired [_] Student [_] Unemployed

17. Please indicate which category best describes **your individual** annual income range:
    [_] Under $20,000 [_] $20,000 to $40,000 [_] $40,001 to $60,000 [_] $60,001 to $80,000 [_] Over $80,000

18. Please indicate how far you travel to get to your most frequented fishing spots or ports (**Excluding boat travel time**).
    [_] Under 1 mile [_] 1-10 miles [_] 11-20 miles [_] 21-30 miles [_] 31-40 miles
    [_] 41-50 miles [_] 51-100 miles [_] > 100 miles

Appendix 2: Post Card Survey

The Donald Bren School of Environmental Science and Management

Channel Islands Charter coast Lobster Survey

This survey is aimed at collecting information regarding the socio-economic drivers of the charter boat recreational spiny lobster fishery in the Channel Islands. It is one of the principal data-gathering components of a graduate school Master's research project being conducted by four students from the Donald Bren School of Environmental Science and Management at UCSB. This investigation will highlight specific drivers of the fishery and the influence these drivers play on harvest. The goal of the research is to create and test methods to estimate the total recreational harvest of spiny lobsters in the Santa Barbara Channel and Channel Islands, in an effort to model the sustainability of the region's fishery. Thank you for your help. Please feel free to search our website (www.lobstersurvey.org) for more information, and do not hesitate to contact us with any questions or concerns at the following email address: Spiny@bren.ucsb.edu

1. How many lobsters did you catch on this trip* (0 to 7)? [_____]
*An **X** if you did not fish for lobster on this trip

2. [What type of gear did you use today? (All that applies)

Skin diving [_____] SCUBA diving [_____] Hoop-neting [_____]

3. Which part(s) of the Channel Islands did you visit on this trip?
(Please circle one or more and state place name if known, such as "Pelicans")

i. Island-_____ Front side or Backside (F or B) [_____] Location-_____

ii. Island-_____ Front side or Backside (F or B) [_____] Location- _____

4. How many times have you gone lobster fishing in the last 12 months? [_____]

5. How many times have you gone lobster fishing in the Channel Islands the last 12 months? [_____]

6. What year were you born? [_____]

7. What is your zip code? [_____]

8. How many people, including you, live in your household? [_____]

9. Which of the following best indicates your household income, before taxes?

[_] Under $20,000 [_] $20,001 to $40,000 [_] $40,001 to $60,000 [_] $60,001 to $80,000 [_] Over $80,000

Appendix 3: OLS Regression Assumptions

A necessary OLS regression assumption test was completed for the regression on the number of trips.

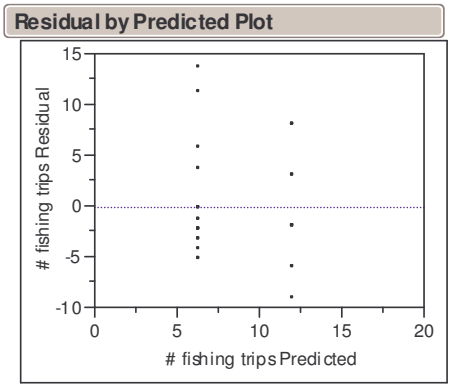
The first assumption that was tested was to see if the model is linear in parameters. This assumption was met when looking at the linear nature of the equation:

$$\#trips = -2.99[MPA] + 9.09$$

The distribution of residuals is not perfectly normal. In order to get even closer to a normal distribution, a $X^{.03}$ transformation could be used (Box-Cox Transformation). However, we estimated that the distribution was close enough to a normal distribution, and did not transform the data:

- the mean and the median are very close to each other (Box plot)
- the distribution has a bell shape (Histogram)
- almost no obvious skewness or kurtosis

The residuals were not found to have constant variance, i.e. were heteroskedastic, as seen in the plot of the studentized residuals against fitted values. The failure of this assumption may indicate that the p-values for the model are unreliable. However, we expected this given the large number of nominal data in our sample.

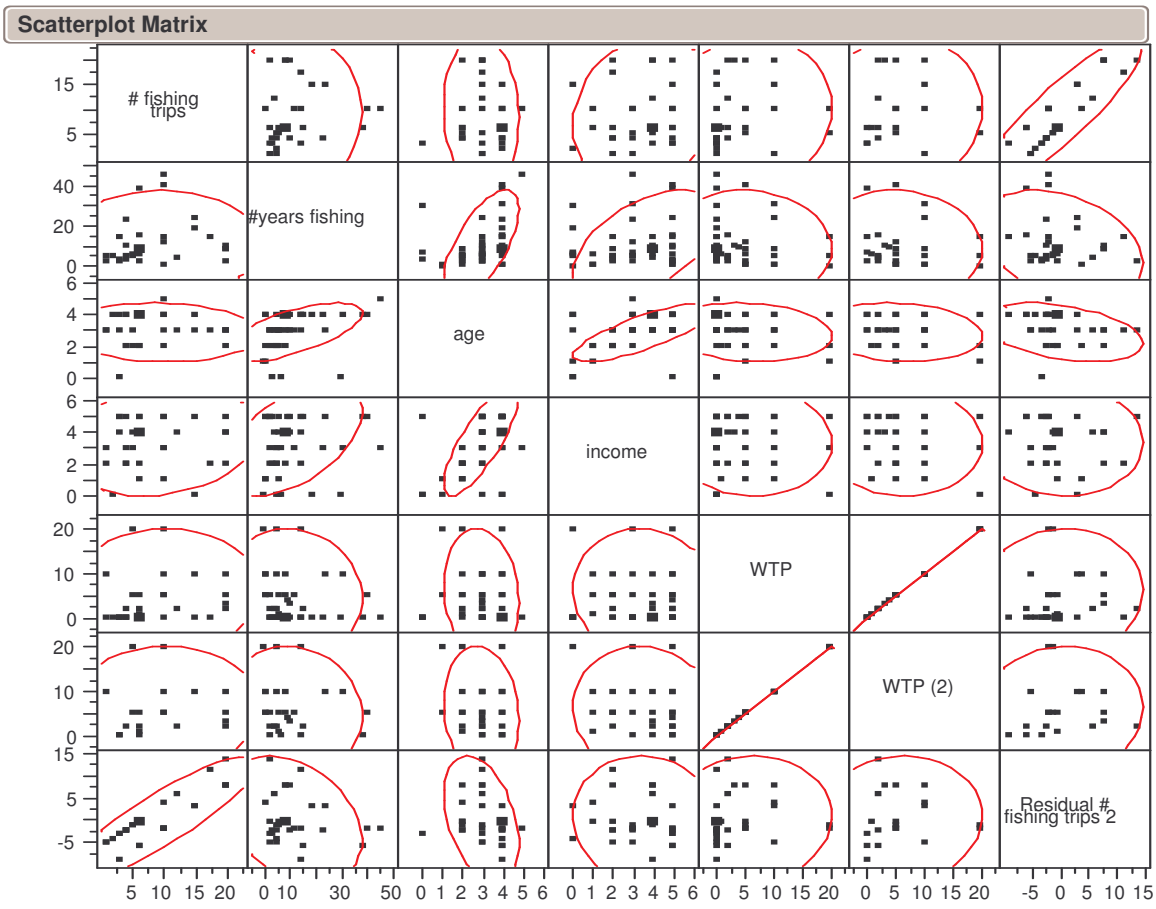


In the data collection method there was bias within the sample population. The majority of the surveys were collected from recreational scuba divers. Therefore our x-value estimates are not precise. The bias was included in the model.

The output model only has one independent variable, thus there can be no co-linearity between independent variables.

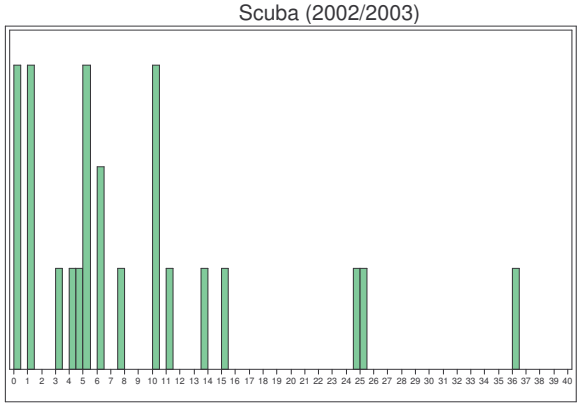
When looking at the component residual plots it is apparent that there may be some nonlinearity in the model, and additional terms may need to be added to the model.

However the residuals were found to be independent and not correlated as seen in the correlation matrix below:

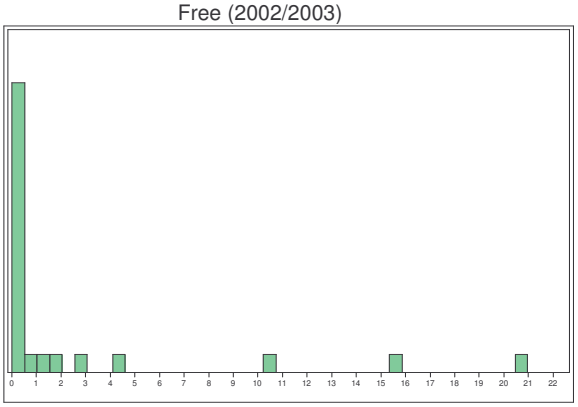

Scatterplot Matrix
fishing trips
#years fishing
age
income
WTP
WTP (2)
Residual # fishing trips 2

Appendix 4: Distribution of Pr{observation}

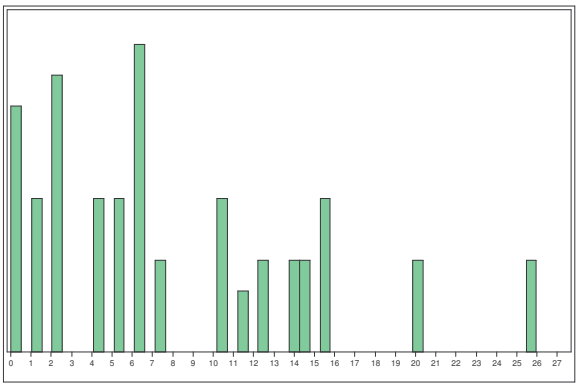
Scuba (2002/2003)



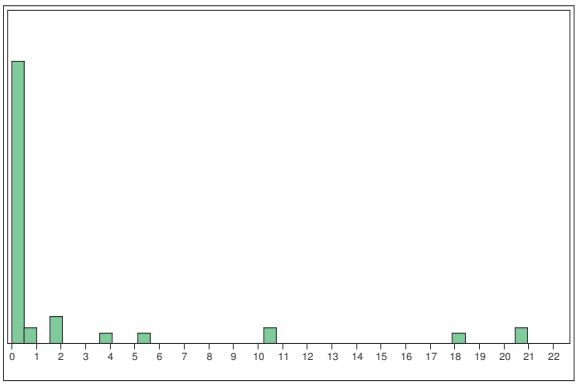
Free (2002/2003)



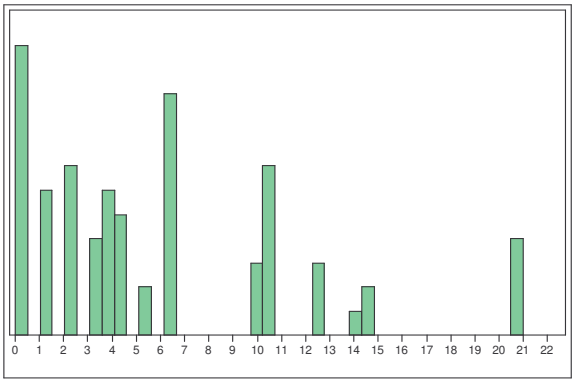
Scuba (2003/2004)



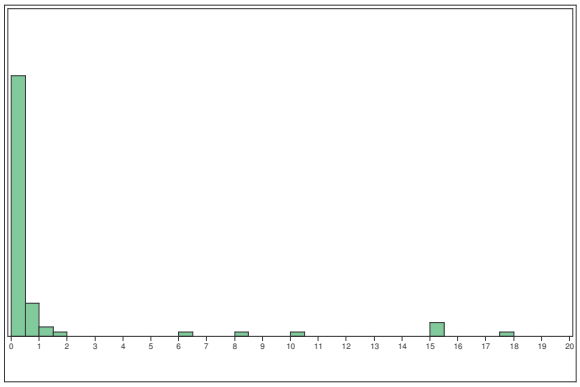
Free (2003/2004)



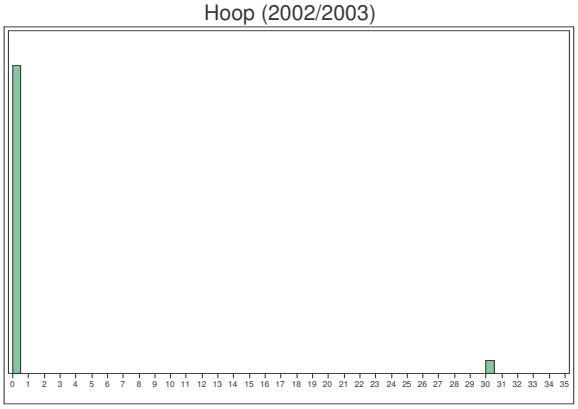
Scuba (2004/2005)



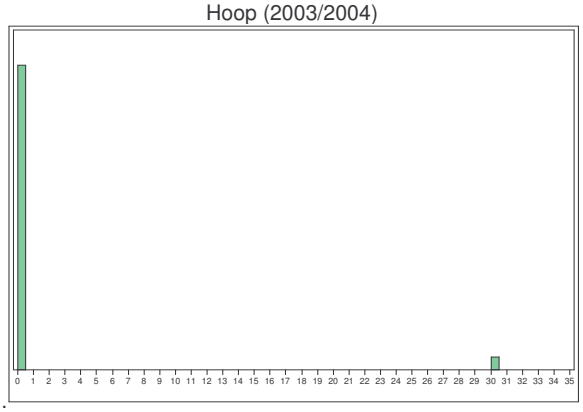
Free (2004/2005)



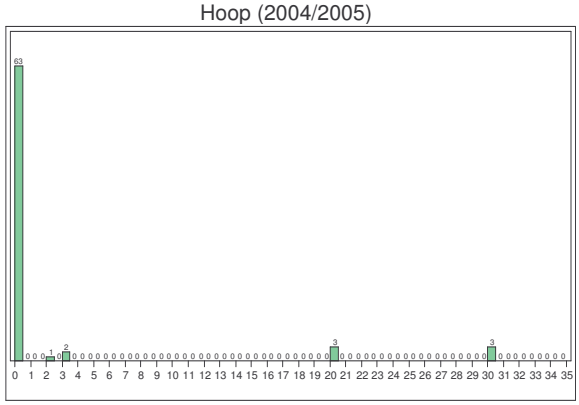
Hoop (2002/2003)



Hoop (2003/2004)



Hoop (2004/2005)



Appendix 5: Parameter estimates used in the function describing fishing efficiency (*e*) by τ

(indicates significance at the 95% level)**

Gear Type	β_0	β_1
Scuba	1.590173	0.066101
Free	0.196497	0.145705
Hoop-net	0.173808**	0.028248**

Appendix 6: Recommended Improved Survey

The Donald Bren School of Environmental Science and Management

This survey is aimed at collecting information regarding the socioeconomic drivers of the recreational spiny lobster fishery. It is the principal data-gathering component of our graduate school Master's research project. This investigation will highlight specific drivers of the fishery and the influence these drivers play on harvest. The goal of our research is to estimate the total recreational harvest of spiny lobsters in the Santa Barbara Channel and Channel Islands, in an effort to model the sustainability of the fishery. Thank you for your help. Please feel free to contact us with any questions or concerns at the following email address: *Spiny@bren.ucsb.edu*

DATE: [_____]

1. What are the factors, or combination of factors, that determine where you fish?
   [_____]

2. What are the factors, or combination of factors, that determine why you fish?
   [_____]

3. What are the factors, or combination of factors, that influence the number of trips you take each season?
   [_____]

4. What are the factors, or combination of factors, that determine what particular gear type (Scuba, Skin-diving, or Hoop Net) you use to fish for spiny lobster?
   [_____]
   [_____]

5. Do you switch lobster fishing gear during a given season? [_] Yes [_] No
   If yes, why: [_____]
   when: [_____]

6. Please indicate the number of years you have been lobster fishing: [____]

7. Did you previously fish in any areas currently designated as marine protected areas? [_____]
   If so, where? [_____]

8. A lobster stamp program consists of an additional charge to the fishing license price in exchange for a stamp that allows you to fish for lobster (similar to the ocean enhancement stamp). This would help quantify the number of recreational lobster fishermen and fund work to further describe and understand the fishery.

Would you support the establishment of a lobster stamp program? [_] Yes [_] No
Why / why not: [_____]
If yes, how much would you be willing to pay: [_____]

Please Indicate:

** If more than one applies, please indicate the percentage of your time devoted to each category*

			For the current season (2005 / 2006)	For the previous season (2004 / 2005)
9. Average number of lobster fishing **trips** you've taken **per season**				
10. Categories that best represent how you've taken lobsters*	Scuba diving		%	%
	Free diving		%	%
	Hoop net		%	%
11. Average number of **lobsters** you've taken **per trip**	Scuba diving			
	Free diving			
	Hoop net			
12. Categories that best represent the location from which you've fished for lobster*	Pier		%	%
	Shore		%	%
	Private boat		%	%
	Charter boat		%	%
	Other		%	%
13. Regions where you primarily fish spiny lobster*	Mainland Santa Barbara county		%	%
	Mainland Ventura county		%	%
	Northern Channel Islands	Santa Cruz Frontside	%	%
		Santa Cruz Backside	%	%
		Anacapa Frontside	%	%
		Anacapa Backside	%	%
		Santa Rosa Frontside	%	%
		Santa Rosa Backside	%	%
		Santa Barbara	%	%
		San Miguel	%	%

14. Please indicate your age:

[_] Under 18 [_] 18 to 29 [_] 30 to 44 [_] 45 to 59 [_] 60 and over

15. Please indicate which category best describes your employment status:

[_] Full Time [_] Part Time [_] Retired [_] Student [_] Unemployed

16. Please indicate which category best describes **your individual** annual income range:

[_] Under $20,000 [_] $20,000 to $40,000 [_] $40,001 to $60,000 [_] $60,001 to $80,000 [_] Over $80,000

17. Please indicate how far you travel to get to your most frequented fishing spots or ports (**Excluding boat travel time**).

[_] Under 1 mile [_] 1-10 miles [_] 11-20 miles [_] 21-30 miles

[_] 31-40 miles [_] 41-50 miles [_] 51-100 miles [_] > 100 miles

Appendix 7: Dynamics of Fishey Access (adapted from Hilborn et al., 2005)

The first level is marked by open access fisheries, which in their simplest form pertain to the lack of any restrictions on participation. Most recreational fisheries of the world are open access, and most commercial fisheries begin in this manner prior to extensive development. The next level of access includes various forms of limited entry, primarily in the form of a fixed number of licenses issued. Participation in these fisheries requires the purchase of a license from an existing participant, or to receive one from an established method of merit ranking. Transferable licenses may become very valuable, especially when the fishery is economically successful. The third level of access is created when the license allows not only access, but carries with it a proportion of either the total catch or effort. These arrangements require a cooperative agreement among fishermen in a limited entry arrangement that specifies allocation among individuals or companies (Hilborn, 2005). Involvement in cooperative fisheries may become very valuable again when permits become transferable. Entry into a cooperative bluefin tuna fishery in Australia has been valued at approximately AU$70 million (Hilborn, 2005). Territorial use rights in fisheries (TURFs) present the highest level of exclusivity in fishery access, and is usually vested on communities of subsistence or small-scale fisheries. Under this scenario, communities own the resources of their area and the right to exclude others from access.