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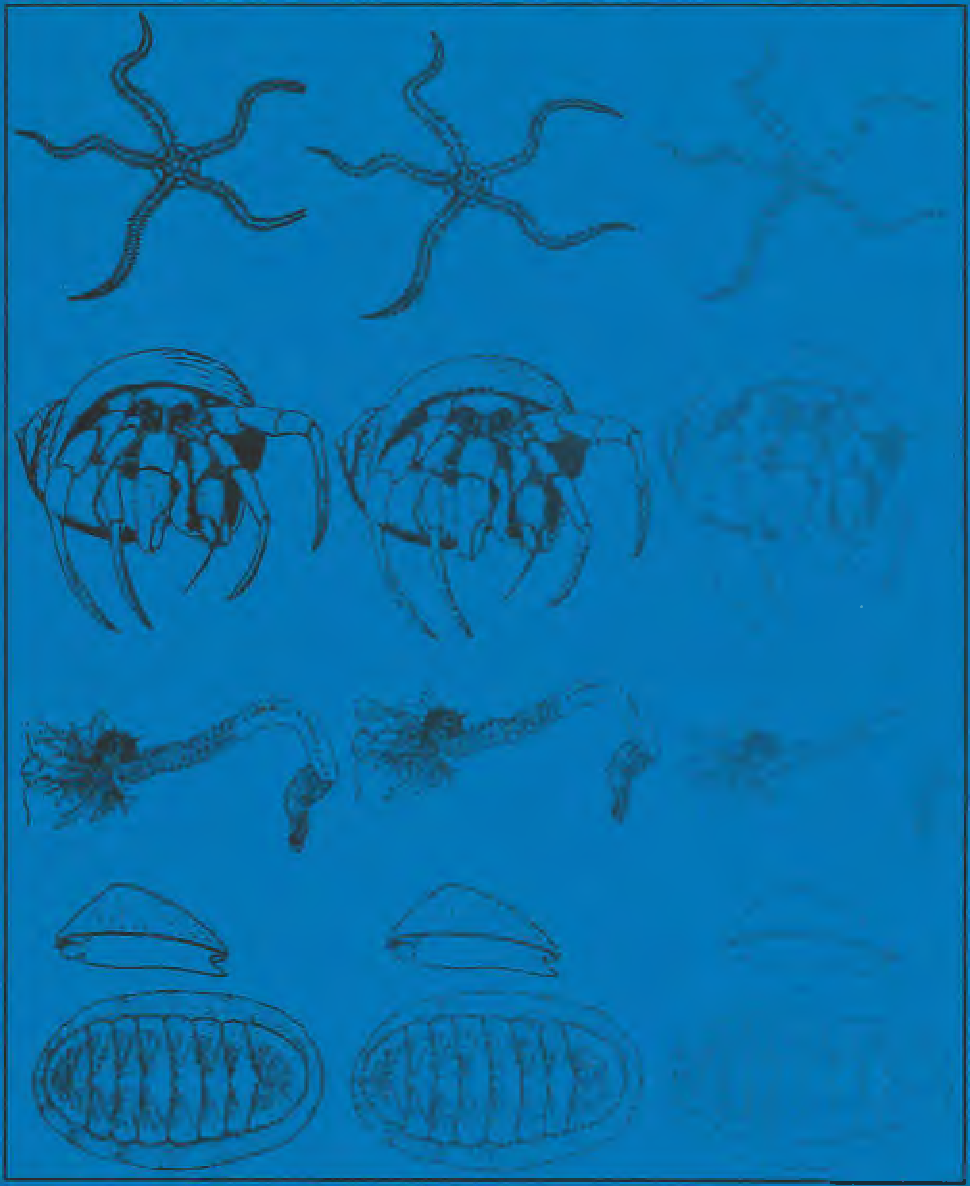
ASSESSMENT OF NONGAME MARINE INVERTEBRATE HARVEST IN WASHINGTON

A Report to the Department of Wildlife
by Diane Carney and Rikk G. Kvitek



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FINAL REPORT

ASSESSMENT OF NONGAME MARINE INVERTEBRATE HARVEST IN WASHINGTON STATE

by

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ABSTRACT

Results of on-site surveys and more than 900 collector interviews, conducted May through August, were used to calculate the 1990 harvest pressure on Nongame Marine Invertebrates (NGMI) from 13 Puget Sound beaches, estimated to be 43,000 collector hours. NGMI are species currently not classified as foodfish or shellfish under jurisdiction of the Washington Department of Fisheries (WDF), or as game under the Washington Department of Wildlife (WDW). The first minus tides of the season sustained the greatest harvest. Harvest pressure generally increased with decreasing tide height. The species most frequently collected from the 13 beaches surveyed were the marine snail, (*Nucella spp.)*, shore crabs, polychaetes, and moonsnails with estimated annual harvests of 119,000; 74,000; 43,000; and 21,000 individuals, respectively. Catch variances were high due to changes in harvest activity with season and tidal height.

"Catch and replace", meaning the collector collected a NGMI from the beach and at some time prior to leaving the site intended to replace the animal back on the beach, was identified as the primary usage of NGMI, followed by collection for food and bait. Asians and Filipinos comprised over 50% of those harvesting NGMI for food or bait. Public school groups comprised 50% of all groups visiting these sites. An estimated 10,000 children from five Puget Sound school districts visited these beaches on field trips in 1990. Over 90% of the students visiting beaches received instruction from their teachers to replace all marine invertebrates and turned-over rocks.

A review of Washington Department of Wildlife's research permits and phone interviews with potential NGMI collector groups revealed over 100 species of NGMI were collected from Washington's waters by universities, schools, private consulting firms, biological suppliers, aquaria and science centers in 1990. These collections included over 9,000 echinoderms 170,000 amphipods and 150,000 polychaetes and 6,000 gastropods. Uses included research bioassay biological supply, education and display.

Baseline NGMI faunal surveys were conducted at 11 exploited, 2 low-exploitation and 3 protected sites. Comparisons of exploited versus protected sites indicated a decline in the abundance of an anemone,*Anthopleura,* the rock jingle,*Pododesmus*, sea stars and terebellid worms at exploited sites. Shore crab densities, however, tended to be higher at exploited sites. Rocks with barnacles on their under-surfaces were more abundant at exploited sites, indicating more frequent turning by collectors.

TABLE OF CONTENTS

1.0 INTRODUCTION

Recent shifts in collection activity and intensity has elicited concern over nongame marine invertebrate (NGMI) harvest from environmental, agency, private and educational quarters (Dethier et al.1989). Except for species classified by the Washington Department of Fisheries (WDF) as foodfish or shellfish (Appendix A) all other invertebrates are non-classified and under Washington Department of Wildlife (WDW) jurisdiction as NGMI. Currently, the harvest of these species is uncontrolled. Harvest pressure on many NGMI species has increased due to:

1. Expanding commercial markets and export of species not traditionally harvested in western countries.
2. Harvest of non-traditional species for consumption by Asian immigrants and other U.S. collectors.
3. Expansion of the use of marine invertebrates for research, bioassay and toxicology.

Expansion of the unregulated harvest of these organisms coupled with increasing disturbance of the intertidal communities by public foot traffic may influence the distribution and abundance of species and decrease the value of Puget Sound tidelands as a recreational, educational , research and commercial resource. Removal of species by collectors, and inter species effects of removal, also may alter natural communities.

These concerns and the absence of basic information about the NGMI harvest and species affected prompted the initiation of this project. Our goals were to:

1. Identify and quantify the major components of the NGMI harvest (the who, what, where, how much, and what for) for selected Puget Sound beaches

2. Establish baselines on current composition of certain harvested species, abundance and size structure at harvested sites as well as control sites for comparison and future monitoring.

The information provided in this study will be useful in identifying those species in greatest need of harvest management, designing managerial strategies to balance recreational and commercial demands upon the NGMI resource, identifying harvester groups (ethnic, organizational, and institutional) with special needs which must be considered for effective future managerial or educational programs, and monitoring changes in NGMI populations on Puget Sound beaches.

2.0 METHODS

Our project had two objectives, each with separate methodologies for investigation.

OBJECTIVE 1. Identify those species of NGMI currently being harvested from Puget Sound beaches, and quantify collector demographics, harvest effort and pressure, and NGMI usage.

OBJECTIVE 2. Collect baseline data on NGMI species for selected Puget Sound beaches. NGMI species larger than 10mm were to be included in baseline surveys.

2.1 OBJECTIVE 1: NGMI HARVEST

2.1.1 Study Site Selection

Seventeen state and county beaches in Puget Sound were selected for NGMI harvest Surveys (Figure 1). Thirteen of these beaches, called "Bucket Survey Sites", were surveyed by our project crews using the protocol described below. The remaining four beaches, called "Volunteer Survey Sites", were surveyed by volunteer crews. These surveys were not conducted using the same protocol as those surveyed by project crews. Consequently, methods and results are summarized separately.

Criteria for site selection were:

1. Evidence of existing NGMI harvest activity from anecdotal information provided by WDW, Friday Harbor Laboratories, private collectors, and our preliminary observations of NGMI harvest on Puget Sound beaches.
2. Accessibility to the public.
3. Reasonable proximity from the project's base of operations in Seattle.

2.1.2 Direct Harvest Evaluation Method Bucket Surveys

Two major factors known to affect intertidal harvest effort are tide height and day of the week (Hockey and Bosman 1986, Underwood and Kennelly 1990). Weather also may dictate the extent of harvest, with more occurring during mild and/or sunny weather. As a result, most intertidal species are harvested during minus tides, with effort peaks on the lowest tides during the daylight hours of spring and summer (Hockey and Bosman 1986, authors pers. obs.).

NGMI bucket surveys were conducted June through August, 1990, during times of expected maximum harvest activity,on days when the tidal height was -1.0 ft., mean low low water (MLLW) or lower during daylight hours. Within these criteria, beach surveys were conducted on 48 out of 59 harvest days. No surveys were conducted during March, April, and May, 1990, due to funding delays. The 1990 season harvest effort and catch estimates were extrapolated from surveys and calculated with the assumption that no harvest occurred on days with low tides higher than -1.0 ft and/or at night. Therefore, harvest estimates were underestimated by some unknown amount.

The day of the week may influence harvest effort and collector demographics, particularly when comparing week-days with week-ends or holidays (Underwood and Kennelly 1990). To allow examination of day-of-week variability, the surveys were divided into two sampling strata: the "weekday" stratum and the "weekend and holiday" stratum. The stratified design method was implemented June 20. Results of surveys conducted before this time were analyzed separately. Beach surveys were performed on the 30 days between June 20 and August 20 with low tides $\leq$ -1.0 ft MLLW. Half of the total 112 available crew-survey days were allotted to each stratum. Beaches were assigned randomly for harvest surveys to days throughout the field season and tidal cycle. Beach survey assignments were made separately by "day-of-week" stratum.

Estimates of the type, extent, duration and effects of NGMI harvest were determined by on-site interviews of persons actively collecting invertebrates (nongame or game), algae and fish from Puget Sound beaches and examination of their collections. Interview sessions began 1 h before and continued for 1.5 h after the tide nadir. The interviewer walked an established survey path (Appendix B) and approached anyone with a container who was collecting or appeared to be intending to collect something from the beach. The interviewer asked the collector a series of questions about the kind of collection they were making. If the collector was intending only to collect classified species such as hardshell clams or dungeness crabs, this was noted along with the number in their party, but further questions regarding NGMI harvest were not asked. Persons collecting or intending to collect NGMI were asked all the questions on the "Bucket Survey" form (Appendix C). Types and amounts of marine algae and fish collected also were noted.

In all but two cases, surveyors were able to locate and question an individual in a collecting group with some command of the English language. Non-English speaking collectors of apparent Asian descent were presented with survey forms translated into Hmong, Korean, Laotian, Vietnamese, Japanese and Cambodian. The surveyor indicated, through gestures, that the collector should select and complete the form written in his language.

School or organization groups were interviewed differently from private groups (see School Survey form Appendix D). The surveyor interviewed the group's representatives (i.e. teachers, chaperones or leaders). In order to determine the general behavior of the group regarding NGMI collection, group leaders were asked the following questions and their answers noted :

1. Has your group been instructed to collect any species in particular?
2. Has your group been instructed not to take home any invertebrates?
3. Has your group been instructed to replace rocks right side up that they have turned over?

The interviewer then walked a transect through the group tallying the species and number of NGMI's collected and replaced, or collected to be taken off the beach. Additionally, the number of rocks turned over and replaced right side up versus the number turned over and not replaced were counted and recorded. No attempt was made to quantify the area of the transect. The data provides only a relative measure of NGMI collection and rock-turning outcome, as well as an idea of the effectiveness of teacher instructions on group behavior.

At the time of the tide nadir, the interviewer scanned the beach survey area using binoculars or spotting scope, and counted the number of all collectors, differentiation between NGMI or non-NGMI collectors was not made. The number of NGMI collectors relative to the number of total collectors was determined from bucket survey data. NGMI harvest effort by beach, tide height and day-of-week, and annual NGMI collection effort and harvest were estimated.

No attempt was made to establish harvest effort per unit beach area. A survey path was established for each beach dictated primarily by beach ownership or topographic barriers to public access. In addition, it was necessary to define a survey path that allowed a clear view of the entire survey area for the nadir counts. Total survey areas varied by beach. The paths (Appendix B) coincided with the beach area most used by collectors.

In some cases, it was possible to interview every collector on the beach throughout the survey interval. At other times, particularly for large beaches with occasionally heavy harvest activity, there was collector emigration and immigration throughout the survey interval in front of and behind the interviewer as he or she followed the survey path which precluded interviewing every collector. Consequently, harvest estimates are conservative.

Daily NGMI harvest effort (E_n) was determined using the formula:

$E_n = E \cdot (an/at)$, where E = the nadir count; an = the number of NGMI harvesters; at = the number of total harvesters.

NGMI harvest pressure (Hp) was determined using the formula:

$Hp = E_n \cdot T$, where T = the harvest duration , or number of harvestable hours for tides 0.0 ft. or less on days with tides of -1.0 ft. or lower. T= 2.26 - 0.55 x the day's low tide. $R^2 = 0.982$.

Estimates of 1990 NGMI catch and harvest pressure were calculated using methods described in Appendix E.

Volunteer Surveys

Volunteer crews surveyed NGMI collection at West Beach , Rosario Beach, Ebey's Landing and Manchester Beach (Figure 1). Selection of survey days for these beaches was not random or stratified as to day-of-week. However, except at Manchester Beach, the bucket survey interview protocol, as outlined above, was followed. The volunteer for Manchester Beach could see the beach from her house. She observed the beach on 9 days. No collection activity was observed. Ebey's Landing was surveyed 8 days. West and Rosario Beaches have the most complete survey coverage with 17 and 16 surveys, respectively, over the course of 8 weeks (June 21 - August 19). Many of the surveys for Rosario Beach occur on consecutive days throughout the week and tidal cycle. For this reason, these surveys were used to ascertain the importance of tidal height and day-of-week on collection activity.

2.1.3 Indirect Harvest Evaluation

WDW Research Permits

NGMI collection information for universities, research institutions, research and consulting organizations, aquaria and science centers, and state and federal agencies was obtained from examination of Washington Department of Wildlife (WDW) research permits for 1990.

Phone Surveys

Information concerning NGMI harvest by public school students, and other groups (research, educational, aquaria, biological supplier, consulting) was gathered from phone interviews with organization representatives.

Schools

A total of 36 elementary schools, 8 middle schools and 8 high schools from five school districts in the Seattle area were surveyed to:

1. Estimate the number of Seattle area students visiting Puget Sound beaches per year on field trips.
2. Determine the average distance classes traveled from schools to beaches.
3. Evaluate the percentage of teachers giving their students instructions not to take home marine invertebrates and to replace rocks they had turned over in the intertidal zone.

Schools for survey were selected randomly from the Seattle phone book.

Other NGMI Collectors

Additional universities, research institutions, consulting organizations, agencies, biological suppliers, aquaria, etc., not identified by WDW as research permittees but suspected to collect NGMI were contacted by phone to determine NGMI use. Most of these collectors were within the Seattle area, however, it became apparent that the extent and diversity of individuals and groups collecting NGMI potentially is great. In almost all cases, each contact with a potential NGMI collector lead to the identification of other potential collectors both within and outside the state of Washington. Approximately one fifth of the number of potential collectors contacted collected NGMI .

2.2 OBJECTIVE 2: BASELINE SURVEYS

Eleven "Exploited" beaches currently sustaining NGMI harvest, and three "Control" beaches, protected from harvest activity, were surveyed to provide baseline faunal information. Control beaches were paired by similarity of habitat and proximity to three of the exploited sites to allow comparison of species abundance and size structure (Figure 1).

2.2.1 Faunal Survey Method

Two 20 m transects were run parallel with the shore in the mid-intertidal zone. Tidal heights of the transects were determined with hand transits. Ten 0.25m^2 quadrats were placed randomly along each transect. All NGMI $\geq$ 10 mm length occurring within the quadrat were identified and counted. Rocks $\geq$ 20 X 20 cm and 40 X 40 cm within the quadrats were measured (length and width), turned over, examined for fauna, and identified as having or not having barnacles (live or dead) on the bottom surface. Barnacle coverage on the underside of a rock indicates it has been turned over. The extent of rock-flipping provides an estimation of the magnitude of collection or general traffic sustained by a site. Because fauna was associated with the undersides of rocks, species densities were defined as density per m^2 of rock bottom surface area.

The first 30 individuals encountered of each NGMI species were measured, to the nearest mm, to determine size structure of the populations. If 30 individuals did not occur within the quadrats, additional quadrats were tossed haphazardly in the vicinity of the transects and measurements taken of target species found within the quadrats. For some species, abundances were low and it was not possible to get 30 measurements.

3.0 RESULTS

3.1 DIRECT EVALUATION

3.1.1 Bucket Surveys

1990 Harvest Pressure

Sampling effort and estimated 1990 NGMI harvest pressure (collector hours) for the 13 "bucket survey" sites are provided in Table 1. Total harvest effort for 1990 at the 13 sites was approximately 43,000 collector hours. Saltwater Point had the greatest harvest pressure at approximately 10000 collector hours. Seahurst (public), Carkeek and Purdy sustained between four and six thousand collector hours. Variances were high due to the effect of tidal height on harvest activity.

Catch Sizes, Species and Uses

Table 2 shows sampled catch sizes and 1990 estimated total catch and uses for selected NGMI species and groups harvested from 13 Puget Sound Beaches.The moonsnail, *Polinices lewisii*, was given a classified status by WDF after commencement of this project and now is considered a game species, but is included in our results. An estimated 119,000 marine snails (*Nucella*); 74,000 shore crabs; 43,000 polychaetes; and 21,000 moonsnails were harvested from the beaches sampled in 1990. Species catch variances were high. Percent composition of NGMI harvests at each site is provided in Table 3. Most collectors collected a few individuals (<10) of a number of species, but some NGMI collectors harvested many individuals of one or two species (Figure 2). Algal harvest also is included, although incidental to the scope of this project. The NGMI's most often collected were shorecrabs, (including in decreasing order of collection: *Hemigrapsus spp., Lophopanopeus sp., Petrolisthes sp.*) and were second only to moonsnails. The use most often stated by collectors for their harvests of shorecrabs, snails, kelp and spider crabs, barnacles, and starfish was "catch and replace", meaning the collector's stated intent was to return the animal to the shore before leaving the site. Moonsnails and the graceful crab,*Cancer gracilis*, as well as a high percentage of *Nucella* were most often collected for food. Polychaetes were collected primarily for bait. Overall, the reason cited most often for collection of NGMI was "catch and replace", followed by food and bait (Table 2, Figure 3).

Ethnic Heritage of Collectors

Over 50 percent of those collectors harvesting NGMI for food and bait were Asian, Korean or Filipino (Figure 4).

Influence of Tide Height and Day-of-week on Collection Activity

The number of NGMI collectors correlated positively with tide height (Figure 5 , t-test $p \leq 0.001$), while the day of the week did not correlate significantly ($p > 0.4$). The greatest collection activity occurs during the lowest tides.

Influence of Season on Collection Activity

The first minus tides in spring may sustain the greatest NGMI harvest for the year. Figure 6 indicates a trend towards diminishing collection activity for three successive minus tides of similar magnitude, as the season progresses. The percentage of NGMI collectors to total collectors remains approximately the same , although different by site (approximately 55% for Alki, and 35% for Purdy), for each survey.

3.1.2 School/Group On-Site Surveys

NGMI Collector Group Type and Beach Visitation

Approximately 70% (n=24) of all groups collecting NGMI were from private or public schools. Other types of groups included church, youth, aquaria-sponsored, and tours conducted by state or county park personnel. Of the 13 beaches surveyed in this study, Saltwater Park had the highest number of groups visiting the beach with 240 surveyed individuals visiting the beach as a group , followed by Mukilteo South (225), Seahurst (193), and Alki with 170.

Beach "Etiquette" Assessment

Approximately 75% of all school groups surveyed (n=17) had been given prior instructions by their leaders or guides to replace, right-side-up, all rocks they had turned over, and to replace all marine invertebrates they had collected. Sixty-six percent of other groups (n=6) had been told to replace all invertebrates, and 33 percent were told to correctly replace turned-over rocks.

<u>Outcome of Group "Etiquette" Instructions on NGMI and Rock Replacement</u>

Individuals in the groups receiving instructions to replace turned-over rocks were much more likely to do so (Figure 7A). Ninety-eight percent of invertebrates collected by individuals in groups instructed to replace them did so, while 60 percent of invertebrates were replaced by individuals from groups not instructed to do so. The difference, however, was not significant (Figure 7B).

<u>NGMI Species collection by Groups</u>

Schools and other groups most often collected shore crabs (65%, n= 299) primarily to be collected and replaced, with anemones and moonsnail egg-cases running distant second and third in frequency of NGMI collection.

3.1.3 Volunteer Surveyed Beaches

No NGMI harvest was observed at Ebey's Landing or Manchester Beach. NGMI harvest activity was low at West Beach, with an average of 3.8 collectors (SD = 4.3, n=17) per survey day. Hermit crabs (41%, n=69) were the most frequent NGMI in collector buckets, followed by barnacles (32%) and limpets (26%). Hermit crabs and limpets primarily were "collected and replaced", while live barnacles were most often cited as being collected for souvenirs. Collector activity was higher at Rosario Beach (9.5 collectors per survey day, SD = 11.6, n=16). NGMI harvest at Rosario was low and most invertebrates were "collected and replaced" although two school groups collected about ten gastropod snails and limpets to take away. The species most often collected were hermit and shore crabs, and limpets (41%, 33% and 30%, respectively, n=111). These species were primarily "collected and replaced".

3.2 INDIRECT COLLECTION SAMPLING

3.2.1 Phone Surveys (Schools)

<u>Percent of Student Classes Visiting Beaches on Field Trips</u>

Phone interviews of teachers in five Seattle area school Districts (Edmonds, Highline, Seattle Public, Mercer Island and Northshore: grades K - 12), revealed approximately 12 percent of the total student body (87384) visited Puget Sound beaches on field trips. Grades K - 6 had the highest proportion of student visitors (15%, n=54346), followed by high school students (8%, n=25239) and middle school students (2%, n=7799) (Appendix F). Of classes that went to the beach on field trips, most visited one beach per year during one of the lowest tides in spring or early summer occurring on a school day (62%, n=52).

The average distance traveled from a school to a beach was about 10 miles (SD=6.9, n=18).

Beach "Etiquette" Instructions

A high percentage of classes were instructed by their teachers to 1) not take marine invertebrates off the beach and 2) replace, right-side-up, rocks that they had turned over (96% and 92%, respectively, n=52).

3.2.2 Phone Surveys (Other NGMI Collectors)

Figures 8 & 9 summarize NGMI collection by aquaria, research and educational institutions, biological suppliers, and environmental consultants. Information concerning NGMI harvest from WDW research collection permits is included. NGMI collections made by these groups are not represented in Bucket Surveys and harvest pressure and catch could not be estimated. Instead, an outline of species targeted and amounts of harvest by group is presented and is expected to represent minimum levels (Appendix G). Macrofauna are those species ≥ 10mm in length and include amphipods and small polychaetes. Microfauna include species < 10mm in length.

Over 150,000 polychaetes and 170,000 amphipods were collected, most often by universities and private consulting/commercial suppliers. *Rhepoxynius abronius*, was the principle amphipod collected (75%). Echinoderms (including sea stars, brittle stars, sand dollars, and sea cucumbers) were the second most collected group at about 9,000 individuals. Over 6,000 gastropods (snails, limpets and nudibranchs) were harvested principally by aquaria.

Aquaria and science centers collected the greatest number of macrofauna (41%), while universities collected the most microfauna (54%). Private consulting and research firms were second in collection amounts for both faunal groups.

3.3 FAUNAL SURVEYS

3.3.1 Paired Control vs Exploited Sites

"Between site faunal variation" as a result of differences in rock sizes was avoided by restricting the range of rock sizes in data analysis (Table 4). Examination of faunal differences at three paired control/exploited sites (Fort Ward/Manchester; McNeil

Island/Steilacoom; Seahurst Private /Seahurst Public) indicate a tendency toward the absence of *Anthopleura, Pododesmus*, terebellid worms and sea stars in the exploited sites. Significantly more rocks had barnacles on their underside at exploited sites, and the number of species found was lower than at control sites (Figure 10). While outside the scope of this project, of particular note was the abundance of midshipmen fish (*Porichthys notatus*) under the rocks at McNeil Island, and their absence at Steilacoom.

Selected species densities are compared for two sets of paired control/exploited sites (McNeil Island/Steilacoom and Seahurst Private/Seahurst Public) in Table 4. Terebellid worms were absent at exploited sites. Densities of *Nucella*, shore crabs and the chiton, *Mopalia*, were lower at the Seahurst Public and Seahurst Private sites, but were not different for the McNeil/Steilacoom comparison. At Seahurst, densities of all species were lower at the exploited (or public) site.

Species sizes were not different at the paired Seahurst sites, but were different for the snail, *Nucella* and shore crabs at the McNeil/Steilacoom paired sites. Species sizes were smaller at the exploited site (Table 5).

3.3.2 Overall Exploited vs Control (Protected) Sites Comparison

A comparison of the average mean densities of species for the eight exploited and three protected sites provides a measure of the possible effects of NGMI harvest and subsequent habitat disturbance. As with the paired sites analysis, some species were found only at control sites (*Anthopleura*, Sea stars, *Tonicella*, limpets, and midshipmen). In addition, *Mopalia*, *Nucella lamellosa*, the rock jingle, and sea cucumbers were significantly higher in the control sites ($p \leq 0.1$, Table 6). Shore crabs were the only species with lower densities in control sites.

3.3.3 Baseline Surveys

Baseline faunal survey results for eleven exploited, three control (protected), and two low exploitation beaches are provided in Appendix H.

Virtually all marine invertebrate fauna in these surveys was either attached to or resided underneath rocks. Consequently, densities are given per m^2 rock-bottom surface area. Faunal densities may be slightly over-estimated because invertebrates attached to the sides and tops of rocks were included in survey counts.

4.0 DISCUSSION

4.1 CONCLUSIONS

This study is the first to identify and quantify the unregulated harvest of NGMI in Washington state. Data from this project will help resource managers determine goals and strategies for management, and identify areas requiring further research of the NGMI harvest. In addition, NGMI population baselines from this study will provide a benchmark against which changes can be gauged. Extrapolation of harvest estimates and impacts from this study, to the entire Puget Sound area should be made with caution. Our estimates are for beaches near metropolitan areas that sustain a high amount of human impact from direct harvest and the effects of foot-traffic and other disturbance. Sections of coastline with restricted access or in more isolated or rural areas, likely will be less affected.

Results from our bucket surveys showed an estimated 43,000 hours (Table 1) were spent during 1990 by collectors engaged in harvesting NGMI at 13 Puget Sound beaches. The NGMI species most often collected were marine snails (*Nucella*), shore crabs (*Hemigrapsus spp., Lophopanopeus sp., Petrolisthes sp.*), polychaete worms and moonsnails (Table 2). NGMI were harvested primarily for non-consumptive or recreational use ("catch and replace"). However, moonsnails (*Polinices sp.*), the marine snail (*Nucella*), and the graceful crab (*Cancer gracilis*) were most often collected for food. The harvest of marine snails (*Nucella*) and even shore crabs for consumption is, apparently, a relatively new phenomenon. It remains to be seen if these species can sustain protracted harvest. Harvest pressure may eventually reduce their numbers below a renewable level with resultant changes in the intertidal community. The marine snail, *Nucella*, is a predator on barnacles. As their numbers decrease barnacle abundance likely will increase (Connell 1970). Ninety percent of polychaete worms and about 30% of the barnacles were collected for bait (Table 2, Figure 3).

Persons of Asian ethnicity represented over 50 percent of those collecting NGMI for food or bait (Figure 4). Some of these people did not speak English, and apparently were recent immigrants from Cambodia, Viet Nam and Laos. However, with two exceptions, an individual with some command of the English language in a predominantly non-English speaking group, was located an questioned about the group's NGMI collection.

Variance in harvest effort, pressure and catch size estimates was high, most probably due to differences in tidal heights on survey days and a pattern of decreasing harvest effort possibly due to a decrease in harvestable organisms with the progression of the season. The greatest harvest effort and catch occurred during the lowest tides and especially on the first lowest tides of the survey season (Figures 5 & 6).

Organizational groups (church, youth, school and park personnel-guided tour) also contributed to NGMI harvest pressure on Puget Sound beaches. Bucket survey results showed school groups comprised a high proportion (70%, n=24) of groups visiting the beaches. From phone surveys we estimated that 12 percent of the student body from five Puget Sound school districts visited these beaches at least once during 1990 on class field trips (Appendix F). Most school children were non-consumptive NGMI collectors. Over 80 percent of teachers interviewed in phone surveys said they instructed their students to replace all organisms that were collected and to correctly re-orient and replace all rocks that were turned over during the course of field examinations. Direct observation of students on the beach indicated that these instructions on beach etiquette were followed by most students (Figure 7). The impact of school groups , and any harvester, on NGMI may be less of harvest than of 1) habitat disturbance when rocks are turned over and organisms handled and 2) disturbance by foot traffic.

Examination of WDW research permits and collecting logs from aquaria, research and private organizations; as well as phone interviews of potential NGMI users (universities and schools, private research or consulting firms, biological suppliers and aquaria and science centers), demonstrated another major NGMI harvest not apparent from our bucket survey results. These users generally targeted particular species and made their collections from sites other than our survey sites. Many of these species live in subtidal or open water habitats and were collected by trawl or SCUBA divers. Many thousands of individuals from > 100 NGMI species were collected by these groups in 1990 (Figure 8, Appendix G). These numbers, however, are undoubtedly underestimates of the total catch because identification of potential users and quantification of their harvest was problematic if their collection permits were not on file with WDW. In particular, anecdotal information from collectors indicated there is a demand for NGMI, being met by commercial suppliers, yet there is no legal framework in the state of Washington within which they must conduct their operations. For this reason, it is not surprising information concerning the commercial harvest of these species was difficult to obtain.

NGMI harvesters collecting for research purposes often targeted species not collected by beach harvesters, in particular, amphipods and micropolychaetes. Amphipods and micropolychaetes are common and ubiquitously, if patchily, distributed in the intertidal. Depletion of these species due to direct harvest is unlikely. Destruction of habitat, through pollution, development, or disturbance by humans, will probably exact a far greater toll on populations.

Faunal surveys of exploited versus protected sites showed anemones , rock jingles, terebellid worms and sea stars to be rarer at exploited sites. These sessile or sedentary species are soft-bodied, fragile or conspicuous, making them more susceptible to decline with increasing disturbance from human traffic, rock flipping or other activities related to NGMI harvest, than other species such as shore crabs. Shore crabs were the only species found to be more abundant at the exploited sites. They may be better adapted to disturbance than other species. Or, their advantage may have been enhanced by the decline of competitors for food and space due to collection, disturbance or some other factor.

Frequency of occurrence of barnacles on the bottom surfaces of rocks in faunal transects showed that 85 percent of the rocks at exploited sites had been flipped versus five percent at the protected sites (Figure 10). Rock flipping is a likely source of mortality to intertidal organisms and may restrict their distribution. Animals living underneath rocks, such as midshipmen or marine worms, may be damaged or killed by crushing when the rock is set down upon them, or they may die of desiccation or predation if the rock is left up-turned and they are exposed to the sun, air and predators. The contrast of midshipmen abundance at the protected McNeil site versus its absence at the paired exploited site at Steilacoom was striking. Midshipmen may be one of the first species to disappear from exploited sites. They are included in faunal surveys because they may lend themselves as a disturbance indicator species for future research. Adults, eggs, and young are particularly sensitive to disturbance by their conspicuousness and accessibility during critical times of their life cycle. During the breeding season, pairs of midshipmen come up into the intertidal, excavate a hole under a rock upon which the female attaches her eggs to the underside. The pair guards the eggs until the eggs break loose (MacGinitie and MacGinitie 1949).

Human harvest and traffic, no doubt, has altered NGMI populations in terms of species composition and abundance, on the 13 Puget Sound beaches surveyed, with cumulative effects for decades if not centuries. It would appear human harvest and disturbance has reduced the numbers of some species to the benefit of shore crabs and possibly barnacles. Soft-bodied and showy organisms fare poorly in or are removed from exploited sites. Other species may suffer from loss of habitat. As these creatures diminish, so does the seashore experience for consumptive and non-consumptive users alike.

Aesthetic, educational, and recreational values decline with the loss of each species and the complex of community and habitat to which it is associated. Because the health of the species cannot be isolated from the community in which it lives, we speculate that habitat protection will be a more effective way of protecting the intertidal resource than species management and harvest regulations. Habitat management protects the intertidal community as an integral complex of interactions between organisms and their environment. The importance of this relationship is neglected when the management focus is on maintaining numbers of a single species. The factors that sustain the species in its community may be overlooked or lost with detrimental consequences for the species.

4.2 LIMITATIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

4.2.1 Estimation of Harvest Effort and Catch Size from Bucket Surveys

High variability in the number of NGMI collectors and the time spent harvesting precluded a precise estimate of harvest effort from bucket survey data (Table 1). Tidal height, weather, season, and day of the week all may have contributed to this variability (Hockey and Bosman 1986; Underwood and Kennelly 1990). Malvestuto et. al (1979), working with the predictive precision of fishing effort from creel surveys determined that the proportional allocation of sampling effort to the degree of variation within a strata provided the best estimates. In keeping with this approach, NGMI surveys were concentrated during expected peak harvest times (on days with tides ≤-1.0 ft. during daylight hours in spring and summer), and at the most frequented locations (13 sites most accessible to the greatest number of people). Previous work on intertidal organism collection (Underwood and Kennelly 1990) and fishing effort (W. Palsson, pers. comm.), indicated that day of week may be critical in determining harvest effort. Upon this assumption, our surveys were stratified into "weekday" and "weekend and holiday" strata. Our results show tidal height to be a more important factor than day of the week (Figure 5). A change in design to randomly sample within a tidal height instead of "day-of-week" strata may increase estimate precision.

Harvest effort estimates from Bucket Survey results were minimums due to three major factors:

> 1.) Bucket Surveys did not begin until June, 1990, when funding became available, and therefore the first minus tides of the spring were not sampled. Preliminary surveys at two sites prior to the onset of this study, during the lowest tides in May, showed the greatest daily number of NGMI collectors for

the project's sampling season for those sites. If future studies or monitoring of NGMI harvest are conducted, survey coverage during the first lowest tides of spring will be critical in determining harvest effort and total NGMI catch for the year .

2.) The sampling design and subsequent analysis assumed NGMI harvest did not take place at night, on days with low tides higher than -1.0 ft., or beyond the time when the tide rises above 0.0 ft. on those days with tides at or below -1.0 ft.. Some level of harvest probably occurred throughout the day and year. Also, there appeared to be a trend of diminishing harvest , during comparable tides, with the progression of the spring and summer seasons (Figure 5). We did not have enough data to incorporate this trend into our harvest estimates.

3. Our results do not include NGMI harvest outside the 13 survey sites in Puget Sound. In particular, we were not able to survey beaches accessible only by boat. One pleasure-craft was observed making periodic landings along the shoreline near Nisqually, unloading bucket-toting persons apparently making some kind of collection. They were logistically inaccessible to our survey crews. This type of harvest strategy probably occurs throughout Puget Sound and may well be a common practice among the most serious NGMI collectors.

The high variance in our catch estimates (Table 2) is in part due to the fact that collectors generally fell into two major categories, recreationalists (those without a specific collecting agenda), and specialists (those with particular target species for collection). Recreationalists collect a few individuals of a variety of species, and accounted for the majority of NGMI harvesters surveyed . The collection is probably opportunistic and of recreational or novelty value, and the invertebrates often may be released before leaving the beach. Specialists , while in the minority, collect and keep a larger number (often >100) of a particular species with a definite use in mind (Figure 2).

The predominate use stated by NGMI collectors was catch and replace (Figure 3). Caution is warranted when categorizing "catch and replace" as a non-consumptive use. It is our opinion mortality of organisms identified as "catch and replace" was high either due to delayed effects of: injury incurred during handling; debilitation caused by prolonged time spent out of the animals' natural environment and in the inhospitable environment of the collectors "bucket"; replacement of the organism in an unsuitable environment (exposed to predation or crushing by foot-traffic, or lacking the necessary habitat requirements to sustain life), or direct consumption by the collector . We feel a collector who stated a consumptive use (food, bait, souvenir, etc) felt confident about his rights to take an animal for these uses, and probably told the truth. However, on-site interview and examination of NGMI collections by surveyors may have produced a suspicion of legal jeopardy or entrapment in some collectors motivating them to misrepresent an intended consumptive use for the non-consumptive "catch and replace" use of their harvest. This may be particularly true where language is a barrier, as is the case for some recent immigrants. Occasionally, a collector saw the approach of our survey interviewer and threw away their harvest, or said they were finished collecting when a visual check sometime later proved they had not. Examination of "catch and replace" shore crab data from bucket surveys shows that of the 48 collectors collecting shore crabs for "catch and replace", 77 percent collected less than 15 individuals each. Only 23 percent of the collectors harvested more than 15 shore crabs apiece, yet their collection accounted for 80 percent of the total "catch and replace" shore crab harvest (Table 7). As defined above, a specialist is likely to target, collect and consumptively use a large number of a few NGMI species. It seems likely that the 23 percent of "catch and replace" shore crab harvesters were collecting for a consumptive use and they misrepresented the intended use of their collection.

No attempt was made to interpret "catch and replace" data for analysis as anything other than such. However, "catch and replace" data are included in harvest estimates and not delimited by consumptive vs nonconsumptive use because:

1.) Although the number of collectors stating a "catch and replace" harvest was high (Figure 3), the "catch and replace" harvest was less than 20 percent for most species and did not contribute substantially to harvest estimates (Table 7).

2.) The "catch and replace" harvest by harvesters collecting <15 individuals of a NGMI species and thus likely to be truthfully stating the nonconsumptive use of their harvest is low (Table 7).

3.) The majority of the "catch and replace" harvest was by "specialists" collecting >15 individuals of a species and probably planning a consumptive use for their harvest even while stating otherwise.

4.) A high percentage of NGMI collected for "catch and replace" probably experienced mortality as a result of collection.

4.2.2 Estimation of Harvest Effort and Catch Size of "other" NGMI Collectors

An important constituency of NGMI collectors undocumented by the bucket surveys were research and private consulting institutions, aquaria and science centers, "commercial" collectors, Friday Harbor Laboratory, and state and federal agencies (Figure 8, Appendix G). These groups never were encountered collecting from the 13 survey sites. This was true in part because their target species do not occur or no longer occur at these sites in the numbers needed for expeditious collection, and because many are subtidal.

Marine invertebrate collections made for research and interpretive display must be made under permit with WDW or WDF. The distinction between collections made for research and those made for bioassay, toxicology testing, or by private companies in their line of business or aquaria supplying out of state aquaria with Washington NGMI, is often ambiguous. Commercial NGMI use and collection is illegal in the state of Washington (RCW 77.16.040). Consequently, many NGMI collectors, either through ignorance or reluctance to admit to their collection activities, do not document their collections through WDW.

The data presented in this report represent a fraction of these types of collectors harvesting Puget Sound NGMI. With the exception of the few organizations on file in WDW research permits, and Friday Harbor Laboratory's *R.V. Nugget* and Ardea Enterprise's collecting logs, other harvesters were arduously tracked by referrals and leads. In some cases, collectors were hesitant to divulge the names of other harvesters, but intimated that, particularly for "commercial" collection, the harvest goes on and is occurring even by groups outside the state. As such, the data is incomplete, but identifies the types and amounts of invertebrates being used and by whom (Figures 8 & 9). Monitoring this harvest and its impact may prove formidable.

4.2.3 Control vs Exploited Site Evaluation

Caution is warranted when evaluating stress on a population (harvest pressure) by comparing abundances of species in an exploited area with a similar but protected (control) area. Differences between sites may be due to human collection activity or spatial variables such as slope of beach, degree of exposure and substratum. Hurlbert (1984) identified this type of flaw as pseudoreplication. The problem of spatial variation can be minimized by comparing the populations' mean densities from several replicate exploited and protected sites. Differences in the average mean abundances between exploited and protected sites can be ascribed, in this case, to NGMI exploitation and includes both harvest and disturbance by rock turning and trampling (Underwood 1989). Additional faunal surveys for these and other areas, particularly control sites, compiled with these data will provide a more definitive analysis of the effects of collection activity on NGMI populations. The most conclusive way to evaluate the impact of humans on intertidal species is through the use of manipulative field experiments in which people are excluded from sections of exploited beaches (Castilla and Duran 1985; Duran and Castilla 1989; as recommended below).

4.3 RECOMMENDATIONS

This study is the first of its kind on the west coast. The primary objectives were to 1.) characterize the NGMI harvest from Puget Sound beaches and 2.) provide baseline faunal surveys at those sites. Should resource managers, biologists, and other interested groups deem this unregulated harvest problematic, our results will aid in identifying information gaps for further research and in developing a marine nongame invertebrate management plan. Three studies are advised regardless of the type of management plan ultimately chosen (sustainable yield, preservation, or unrestricted harvest):

4.3.1 Assessment of the Effects of Harvest on NGMI Species and Populations

One of the best ways to gauge the effects of harvest would be to cordon-off areas of beach (termed exclosures), or in some other way protect from human disturbance, sections of beaches currently sustaining NGMI harvest. Comparison of NGMI population structure over time (in terms of species abundances, diversity and species size structure), from adjacent protected and exploited sites will afford the best view of harvest impacts. In this way, the rate of recovery and resilience of NGMI species can be assessed. This approach, carried out on short sections of shore in central Chile, has been used to demonstrate the profound community wide effects of human harvest of intertidal invertebrates (Castilla and Duran 1985; Duran and Castilla 1989). We strongly recommend similar studies be initiated at several of our most intensely harvested sites as a short term experiment (3-5 yrs) which may be extended as long term experiments or as preserves to serve as reference communities. A related experiment also could be used to test the impact of rock turning alone on the diversity, abundance and size structures of intertidal species. Selected rocks could be flipped and replaced or not replaced at different frequencies within shore plots from which people have been excluded.

4.3.2 Identification of the Life History and Habitat Requirement For NGMI Species

An understanding of the biological constraints and environmental needs of a species is an essential but often neglected requirement for effective management. For example, identification of source stocks for NGMI species recruitment into harvested sites, is imperative when planning harvest levels. For some species, harvested sites may be restocked by recruits from adjacent privately owned tidelands (approximately 60% of Puget Sound, J. Thomas, pers. comm.). Species that seasonally migrate between shallow and deep water may be more or less adversely effected depending on their vulnerability to harvest during critical life stages.

4.3.3 Research on the Extent of the Algal Harvest and its Effect on NGMI

The marine algae community must be considered integral to marine fish and invertebrates because it provides them food, protection and habitat. Our results show approximately 8,000 gallons of marine algae were harvested from 13 Puget Sound sites in 1990 (Table 2). This represents a substantial loss of habitat and food for some NGMI species.

4.4 PROBLEMS WITH THE CURRENT REGULATORY SYSTEM

4.4.1 Research Permits

WDW's research permit system documents NGMI collections made for the purpose of research or education. Collections made by aquaria are included in this category as are those made by consulting and research companies for bioassay, toxicology and other uses. Compliance in filing a permit is spotty at best, and there is ambiguity between collections made for research and education, and collections made for research-for-profit or display-for- profit. WDW issues research permits for NGMI collection to biological supply houses, aquaria, consulting companies and others for their profit-making ventures. There is a market for these species, and suppliers fill the demand. In particular, certain bioassay and toxicology protocols require testing with a single species. As the usefulness of these species in pollution assessment grows, so will the demand, and research collection enters the realm of a commercial enterprise. Another source of ambiguity of collections made under WDW research permits is the harvest of NGMI by commercial day-cruise ventures in Puget Sound. Customers pay to cruise the Sound, and as part of the educational experience, NGMI are collected by dredge or tow for customer examination. Their harvest may be non-consumptive, but even if the organisms are returned to the water, some impact will be sustained. It is necessary to define and allow for the commercial collection of these and other species within the regulatory framework. A review of the NGMI collected by research and other groups (Appendix G) will help to identify species or types of collection warranting particular attention.

Research permits are filed prior to the NGMI collection. Accuracy of these documents is subject to the permittees honesty in compliance to a stated collection and thoroughness in identifying locations and dates of collection. WDW currently does not follow-up with a comparison of stated versus actual collection, nor is permit information used in management planning (R. Sherry, pers comm.).

An overhaul of the method and use of the research permit system could yeild valuable information on the NGMI harvest with moderate expense and effort. At the very least, under the present permitting system, it would be prudent to elicit research permit application of a higher percentage of collectors than presently occurs. This includes state and federal agencies. A notice sent to potential collectors (research institutions, environmental consulting companies, aquaria, biological suppliers, day-cruise operations, etc.), reminding them of the need to obtain a collecting permit from WDW, may increase compliance and provide a better idea of the NGMI harvest at minimal effort. Accurate log keeping of NGMI collection also should be stressed. The use of words like "some" or "many" in describing the extent of a collection are meaningless and should be discouraged. More quantitative records and an annual summary will enable agencies to monitor changes in catch-per-unit-effort and species harvested thus provide an indirect measure of changes in resource abundance.

4.4.2 NGMI Harvest Enforcement

Managers may identify the need for regulation of the NGMI harvest. Any type of regulation is only as good as the degree to which it is adhered. A management plan will have to be publicized and understood throughout the collecting community.

Special attention should be given to the non-English speaking constituency of NGMI collectors. Recent immigrants in particular, may be unfamiliar and culturally at odds with Washington's current regulations. They will require special educational attention. The state of California has had some minor problems with adherence to wildlife regulations by individuals of non-English speaking (in this case Southeast Asian) communities. They have dealt with this by establishing a liaison (usually one of their enforcement officers) with Southeast Asian community organizations. The liaison is invited or asks to be invited to speak, with the aid of a translator, to these organizations about current regulations and why they are necessary. Translated regulations are disseminated. Often these invitations are a result of a series of court notices concerning wildlife violations incurred by members of the community (D. Johnson, California Dept. of Fish and Game, pers. comm.).

4.5 MARINE INVERTEBRATE MANAGEMENT IN CALIFORNIA & OREGON

California and Oregon state agency personnel report little problem with the collection of NGMI, although the harvest of marine algae is becoming an issue (R. Collins, California Dept. of Fish and Game, pers. comm.). The following is a summary of marine invertebrate harvest regulations in these states.

The California Department of Fish and Game (CDF&G) authorizes the commercial take of marine invertebrates, including the following species: barnacles, sand crabs, limpets, mussels and sand dollars, nudibranchs, starfish and worms under permit to licensed commercial fishermen. Other marine invertebrates may not be taken. Marine invertebrates may be collected for research and education under a scientific collection permit. There is no recreational collection of invertebrate species within 1000' MLLW of shore with the exception of marine worms, turban snails, and sand dollars. For these species, the daily bag limit is 35 (California Sport Fishing Regulation 29.05, 1990).

In the early 1950's, public outcry over the denuding of marine invertebrates by collectors from rocky tidepools spurred CDF&G to set up ecological reserves of major accessible tidepool areas. Marine invertebrate collection is prohibited in these reserves. Concern over the harvest for food of marine invertebrates by Asians, recently immigrated to California, fueled a second wave of public concern in the early 1970's. CDF&G responded by implementing the regulations currently in place. Anecdotal information indicates some rebounding of abundances of marine invertebrate species in reserves with adequate enforcement effort. State regulations in some reserves are enforced, cooperatively, by county law enforcement entities. Restriction of access to a few well monitored points of entry facilitates enforcement (R. Collins, pers comm.).

In Oregon, there is no commercial harvest of intertidal animals without a commercial fishing or bait permit (Oregon Wildlife and Commercial Fishing Code 635-05-090). There is no limit on the recreational harvest of sand crabs, kelp worms and turban snails. The daily catch limit on all other marine invertebrates is 10 in aggregate. In addition, Oregon has identified a number of sites as "Permit Areas". These areas are closed to the taking of marine animals except for education or research under permit (Oregon Sportfishing Regulations, 1990).

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5.0 REFERENCES

California Sport Fishing Regulation 1990-1991. California Dept. of Fish and Game, 1416 Ninth St., Box 944209, Sacramento, CA 94244-2090 27 pp.

Castilla, J. C. and L. R. Duran. 1985. Human exclusion from the rocky intertidal of central Chile: the effects on C. concholepas (Mollusca: Gastropoda: Muricidae). Oikos 45: 391-399.

Collins, R. California Dept. of Fish and Game. Marine Resources Division. P. O. Box 944209, Sacramento, CA 94244-2090.

Connell, J. H. 1970. A predator-prey system in the marine intertidal region. I. Balanus glandula and several predatory species of Thais. Ecol. Monogr. 40(1): 49-78.

Dethier, M. N., D. O. Duggins, and T. F. Mumford Jr. 1989. Harvesting of non-traditional marine resources in Washington state: Trends and concerns. Northwest Environmental Journal. 5: 71-87.

Duran, L. R. and J. C. Castilla. 1989. variation and persistence of the middle rocky intertidal community of central Chile, with and without human harvesting. Mar. Biol. 103: 555.

Hockey, P. A. R., and A.L. Bosman. 1986. Man as an intertidal predator in Transkei: disturbance, community convergence and management of a natural food resource. Oikos. 46: 3-14.

Hurlbert S. H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs. 54: 187-211.

Johnson, D. Pers. Comm. 1990. California Dept. of Fish and Game, Law Enforcement Division, 1416 Ninth St., Box 944209, Sacramento, CA 94244-2090.

Kyte, M. A. 1989. The nongame marine invertebrates of Washington: An inventory of species and sources of loss with a status evaluation and management and conservation guidelines. Washington Department of Wildlife - Nongame Program.

MacGinitie, G. E. and N. MacGinitie. 1949. Natural history of marine animals. McGraw-Hill Book Co., Inc. N.Y. 473 pp.

Malvestuto, S.P.,W.D. Davies and W.L. Shelton. 1979. Predicting the precision of creel survey estimates of fishing effort by use of climatic variables. Trans. Am. Fish. Soc., 108: 43-45.

Oregon Sport Fishing Regulations 1990. Oregon Dept. of Fish and Wildlife, 2501 S 1st- P. O. Box 59, Portland, OR 97207 38 pp.

Oregon Wildlife and Commercial Fishing Codes 1989-90. Oregon Dept. of Fish and Wildlife, P. O. Box 59, Portland, OR 97207 p. 60-61.

Palsson, . A. 1990. Pers. Comm. Washington Dept. Fisheries, Marine Fish Program, 7600 Sand Point Way N.E. Bin C15700, Bldg. 4/2129, Seattle, WA 98115.

RCW (Revised Code of Washington) 1989. Vol. 6 Title 77. Statute Law Committee. Olympia, WA. p. 40.

Sherry, R. 1991. Pers. Comm. Washington Department of Wildlife, 600 Capitol Way N., Olympia, WA 98501.

Thomas, J. Aquatic records manager, Washington Department of Natural Resources, South Puget Sound Region Office, 28329 SE 448th, Enumclaw, WA.

Underwood, A.J. 1989. The analysis of stress in natural populations. Biological Journal of the Linnean Soc. 37: 51-78.

Underwood, A.J. and S.J. Kennelly. 1990. Pilot studies for designs of surveys of human disturbance of intertidal habitats in New South Wales. Aust. J. Mar. Freshwater Res., 41: 165-73.

Table 1. Sampling effort and nongame harvest pressure at the 13 Puget Sound bucket survey sites. Number of survey days, total number of collectors interviewed, and the percent of collectors with non-game species are given for each site. Estimates for total nongame harvest effort (En: number of collectors) and harvest pressure (number of collectors x hours available for harvest) are based on 59 days in 1990 with tides below 0.0 ft occurring during daylight hours (see text for details).

		Collectors Surveyed		Total Nongame Effort Estimated for 1990 season	
Site	Days sampled	Total (Ind)	Percent Nongame collectors	Collectors (En) ± SD	Harvest Pressure (collector hrs) (En·T) ± SD
Alki	8	193	66%	943 ± 616	3232 ± 2830
Carkeek	8	198	63%	1207 ± 975	4607 ± 3927
Edmonds	9	392	35%	1136 ± 1539	3807 ± 6528
Flagler	8	250	16%	358 ± 133	1187 ± 588
Golden Gardens	7	114	54%	599 ± 747	1992 ± 3065
Mukilteo N	9	100	42%	326 ± 255	931 ± 827
Mukilteo S	7	147	87%	840 ± 1284	2520 ± 5247
Picnic Point	9	248	10%	139 ± 104	453 ± 328
Purdy	13	608	34%	1049 ± 877	4167 ± 5097
Seahurst	9	445	65%	1866 ± 3001	6181 ± 12215
Saltwater Pt.	10	435	94%	2817 ± 3737	9724 ± 16088
Tatsolo/Steilacoom	11	163	58%	500 ± 403	1875 ± 2092
Titlow	11	152	72%	573 ± 700	2072 ± 3199
All sites combined	119	3445	52%	12,353 ± 5,513	42,748 ± 23,510

Table 2. Catch sizes and reported uses of NGMI and algal harvest at 13 Puget Sound beaches. Actual Catch is the sum of all collections observed and counted in the containers of all 903 collectors interviewed during the buckets surveys. Total 1990 Catch is the estimated harvest of each catch-type for all 13 Puget Sound survey sites calculated for the 59 days in 1990 with tides below 0.0 ft occurring during daylight hours.

				Uses of Non-Game species as given by surveyed collectors					
Species	Actual Catch	Total 1990 Catch x 10^3 (Estimate ± SD)	Occurrence in collector buckets	Catch & replace	Food	Bait	Souvenir	Art	Other
Algae	314 gal	8 ± 6 gal	8 %	10 %	54 %	28 %	0 %	0%	8 %
Shorecrabs	2344 ind	74 ± 53 ind	10 %	58 %	4 %	19 %	10 %	0 %	9 %
Nucella	2111 ind	119 ± 85 ind	3 %	36 %	32 %	4 %	14 %	11 %	3 %
Moonsnails	1625 ind	21 ± 20 ind	12 %	33 %	59 %	2 %	2 %	0 %	4 %
Polychaetes	1564 ind	43 ± 32 ind	8 %	6 %	0 %	90 %	0 %	0 %	4 %
Barnacles	797 ind	45 ± 70 ind	2 %	53 %	0 %	28 %	1 %	1 %	18 %
Kelp & spider crabs	144 ind	5 ± 5 ind	3 %	84 %	4 %	4 %	0 %	0 %	8 %
Cancer gracilis	83 ind	2 ± 3 ind	2 %	25 %	67 %	0 %	8 %	0 %	0 %
Starfish	68 ind	2 ± 2 ind	3 %	76 %	0 %	0 %	16 %	0 %	8 %

Table 3. Percent composition of actual nongame marine invertebrate harvests at each site. N = total number of NGMI individuals counted in collector buckets for all survey days.

Site	Shore crabs	*Nucella*	Moon snails	Worms	Barnacles	Kelp & spider crabs	Star fish	*Cancer gracilis*
Alki	18%	65%	1%	2%	7%	1%	1%	0%
Carkeek	34%	2%	17%	12%	8%	6%	0%	0%
Edmonds	4%	6%	40%	2%	6%	4%	0%	0%
Flagler	28%	9%	0%	19%	0%	3%	3%	0%
Golden Gardens	39%	0%	19%	7%	21%	0%	0%	0%
Mukilteo N	0%	1%	0%	93%	6%	0%	0%	0%
Mukilteo S	32%	5%	0%	40%	0%	0%	2%	0%
Picnic Point	18%	25%	13%	18%	25%	0%	0%	0%
Purdy	9%	0%	66%	3%	3%	0%	1%	4%
Seahurst	48%	18%	18%	0%	0%	13%	0%	0%
Saltwater Pt.	64%	0%	3%	24%	1%	2%	3%	0%
Tatsolo/Steilacoom	7%	27%	2%	18%	38%	0%	0%	0%
Titlow	32%	46%	0%	3%	2%	0%	0%	0%
Total harvest	24%	22%	17%	16%	8%	1%	1%	1%

Species contributing to majority of individuals in "Other" catagory: * hermit crabs, † sand dollars, ∞ other gastropod snails.

Table 4. Differences in disturbance level and NGMI abundance (mean ± SD) at paired non-harvested and harvested sites. If sampled rocks had barnacles (dead or alive) on the undersurface they were classified as previously turned. ns = no significant difference between means (P < 0.05).

	Rocks			Species associated with rocks (means ± SD)			
Site comparisons	Size mean ±SD (m^2)	Previously turned-over* (%)	Rocks sampled (N)	Terebellid worms (ind/m^2)	*Nucella* snail (ind/m^2)	Shore crabs (ind/m^2)	*Mopalia* chiton (ind/m^2)
Non-harvested-1							
McNeil Is.	0.1 ± 0.03	0 %	14	14 ± 17	3 ± 9	47 ± 44	2 ± 5
Harvested-1							
Steilacoom	0.1 ± 0.03	50 %	16	0 ± 0	31 ± 53	44 ± 152	12 ± 29
t-test comparison	ns			p = 0.004	ns	ns	ns
Non-harvested-2							
Seahurst - private	0.1 ± 0.01	14 %	29	2 ± 9	61 ± 61	39 ± 38	5 ± 10
Harvested-2							
Seahurst - public	0.1 ± 0.01	92 %	67	0 ± 0	3 ± 10	14 ± 23	< 1 ± 0
t-test comparison	ns			p = 0.03	p = 0.0001	p = 0.0001	p = 0.004

Table 5. Sizes (means ± SD) of selected NGMI at paired non-harvested and harvested sites. ns = no significant difference between means ($P < 0.05$).

Site	Species sizes (means ± SD) *Nucella lamellosa* (mm)	Shore crabs (mm)	*Mopalia* chiton (mm)
Non-harvested-1			
McNeil Is.	42 ± 11	30 ± 8	45 ± 5
(N)	(32)	(39)	(5)
Harvested-1			
Steilacoom	16 ± 12	13 ± 5	41 ± 23
(N)	(32)	(40)	(15)
t-test comparison	p = 0.0001	p = 0.0001	ns
Non-harvested-2			
Seahurst - private	34 ± 8	18 ± 5	67 ± 13
(N)	(99)	(49)	(13)
Harvested-2			
Seahurst - public	35 ± 5	17 ± 4	66 ± 15
(N)	(24)	(24)	(15)
t-test comparison	ns	ns	ns

Table 6. Differences in nongame faunal abundances (mean ± SD ind/m^2 of rock surface area) at exploited (n = 8) and protected (n = 3) sites in Puget Sound. Faunal densities are means of the mean faunal densities calculated from transect data collected at individual sites. P-values are from ANOVA test for each faunal group. P is the probability that the means come from different populations.

	Exploited sites (ind/m^2)	Protected sites (ind/m^2)	p
CNIDERIA			
Anthopleura (anemone)	0.0 ± 0.0	5.0 ± 8.7	0.10
MOLLUSKS			
Tonicella (chiton)	0.0 ± 0.0	1.3 ± 1.2	0.006
Mopalia (chiton)	1.3 ± 2.8	6.7 ± 5.7	0.059
Limpets	0.0 ± 0.0	1.0 ± 1.7	0.10
Nucella lamellosa (snail)	22.0 ± 34.0	23.2 ± 33.0	0.002
Rock jingle	0.1 ± 0.4	15.6 ± 16.3	0.016
POLYCHAETES			
Terebellids	3.4 ± 9.6	12.3 ± 10.0	0.20
CRUSTACEANS			
Shore crabs	56.5 ± 40.8	39.0 ± 27.0	0.52
Hermit crabs	5.1 ± 9.9	5.3 ± 7.6	0.17
Kelp crabs	0.1 ± 0.2	0.3 ± 0.4	0.32
ECHINODERMS			
Sea stars	0.0 ± 0.0	0.4 ± 0.6	0.07
Sea cucmbers	0.1 ± 0.4	12.7 ± 20.2	0.08
FISH			
Midshipmen	0.0 ± 0.0	1.3 ± 2.3	0.10

Table 7. Reliability and importance of "catch and replace" (C&R) as a "Use" category reported by surveyed NGMI collectors. Although many collectors gave C&R as the reason for collecting NGMI (Fig. 3), few of them collected ≥ 15 ind. Those that did collect ≥ 15 ind, however, accounted for the majority of the C&R catch for most species, and may have been reluctant to reveal their true intentions. The percentage of the total measured NGMI harvest (harvest values given in Table 2) attributable to collectors claiming C&R was highest for crabs and starfish. In actuality, these C&R values may be inflated due to collector reluctance to be truthful.

NGMI species	Collectors claiming C&R (ind)	Percentage of C&R collectors holding ≥ 15 ind	Total C&R catch (ind)	Percent of C&R catch taken by collectors holding ≥15 ind	Percent of actual NGMI harvest taken by collectors claiming C&R
Shore crabs	48	23%	837	80%	36%
Nucella spp.	10	10%	70	70%	3%
Moonsnails	34	0%	79	0%	5%
Polychaetes	4	25%	21	71%	1%
Barnacles	8	24%	82	50%	10%
Kelp & Spider crabs	21	19%	136	59%	94%
Cancer gracilis	3	0%	14	0%	17%
Starfish	14	7%	44	57%	65%

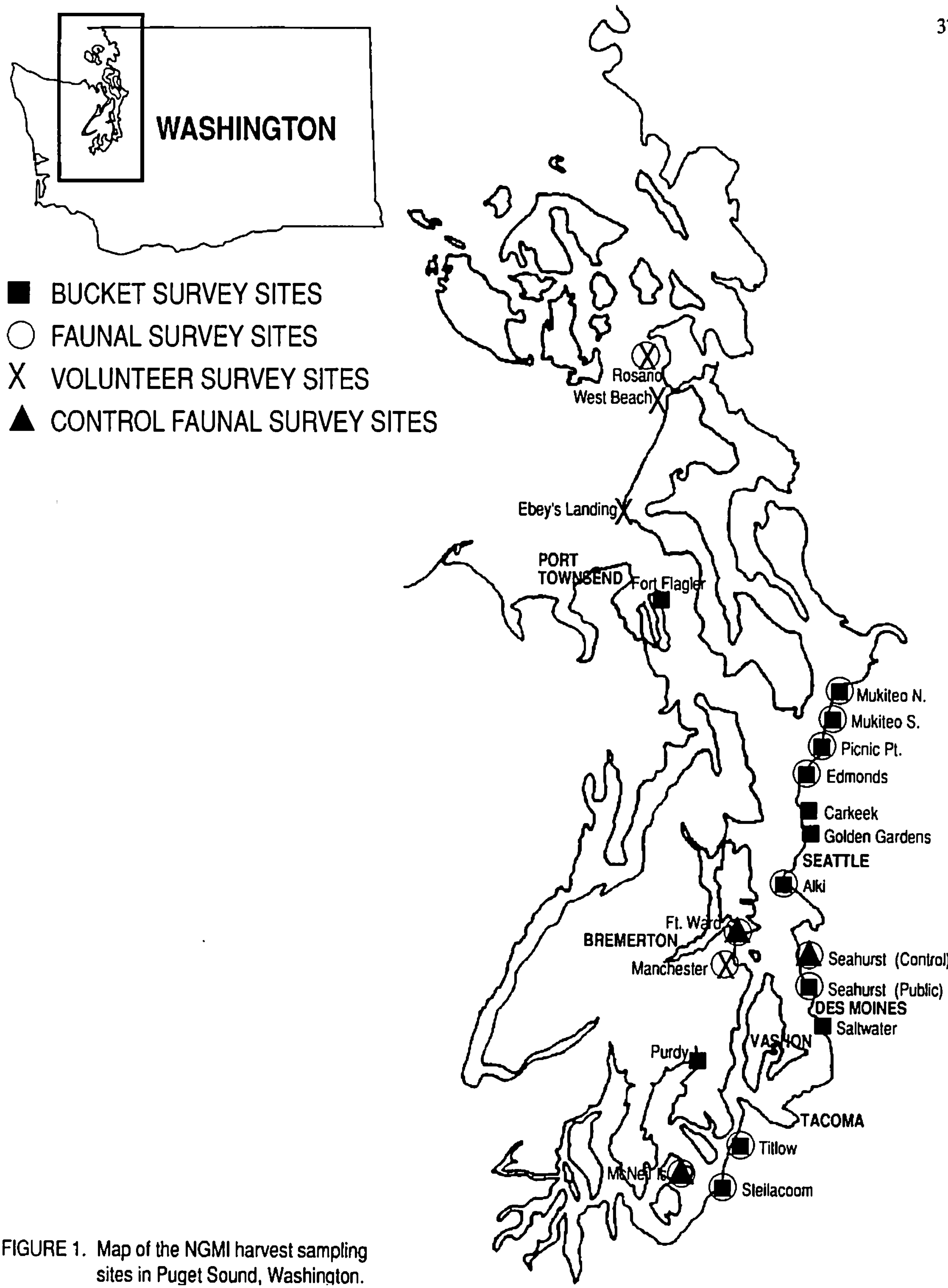
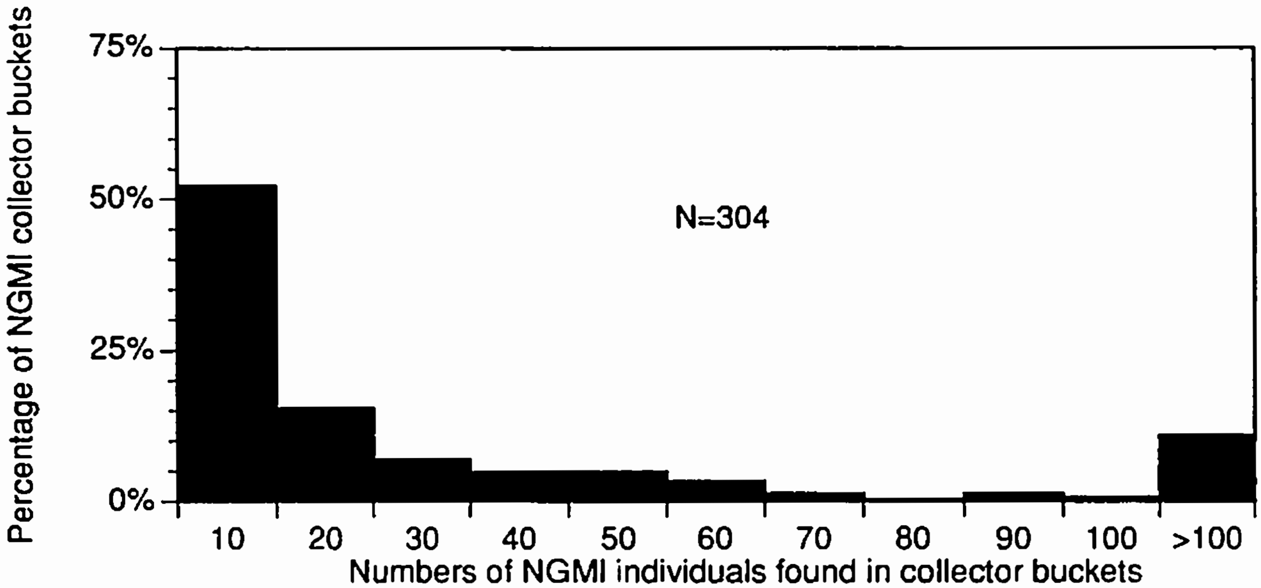


FIGURE 1. Map of the NGMI harvest sampling sites in Puget Sound, Washington.



A. Data from bucket surveys show most NGMI collectors (>50%) collect a few individuals (≤ 10) in aggregate. These collections probably are made for their recreational, not consumptive, value. However, about 10% of collectors harvest > 100 NGMI individuals indicating a specific harvesting agenda.

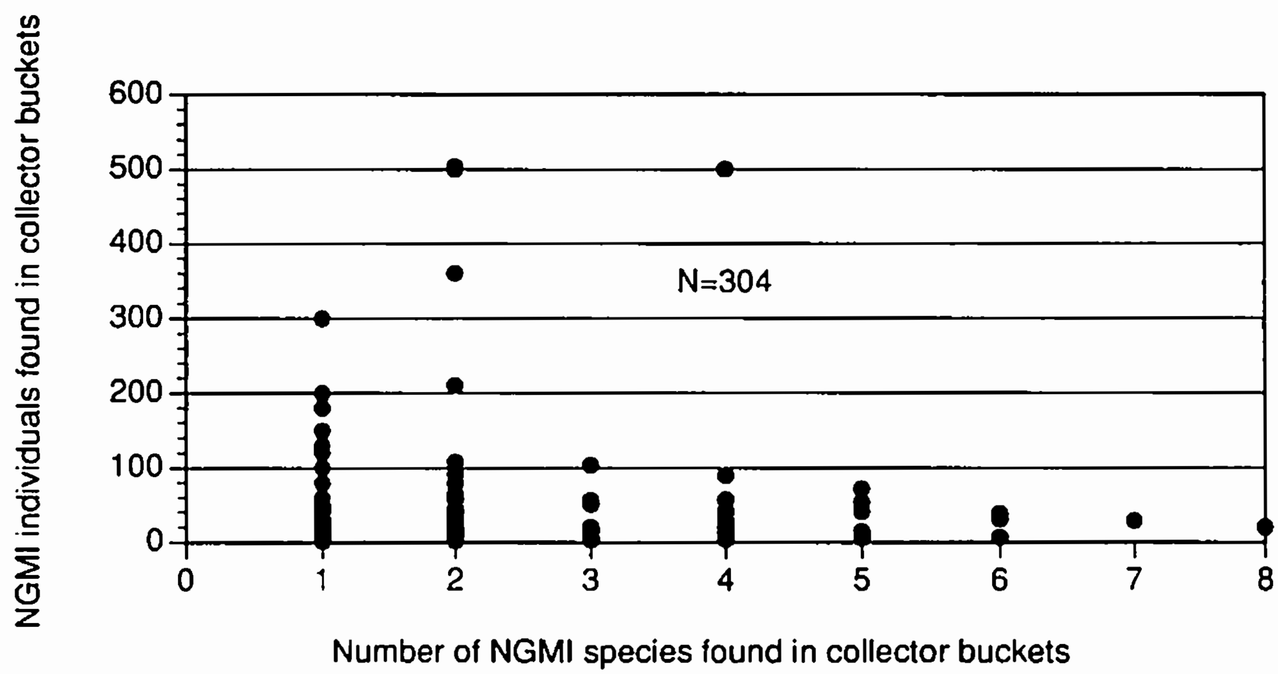


FIGURE 2. B. Species diversity is inversely related to the number of NGMI individuals found in collector buckets (from Bucket Survey results). Collectors either target and harvest a large number of a particular NGMI species, or a few of a number of species.

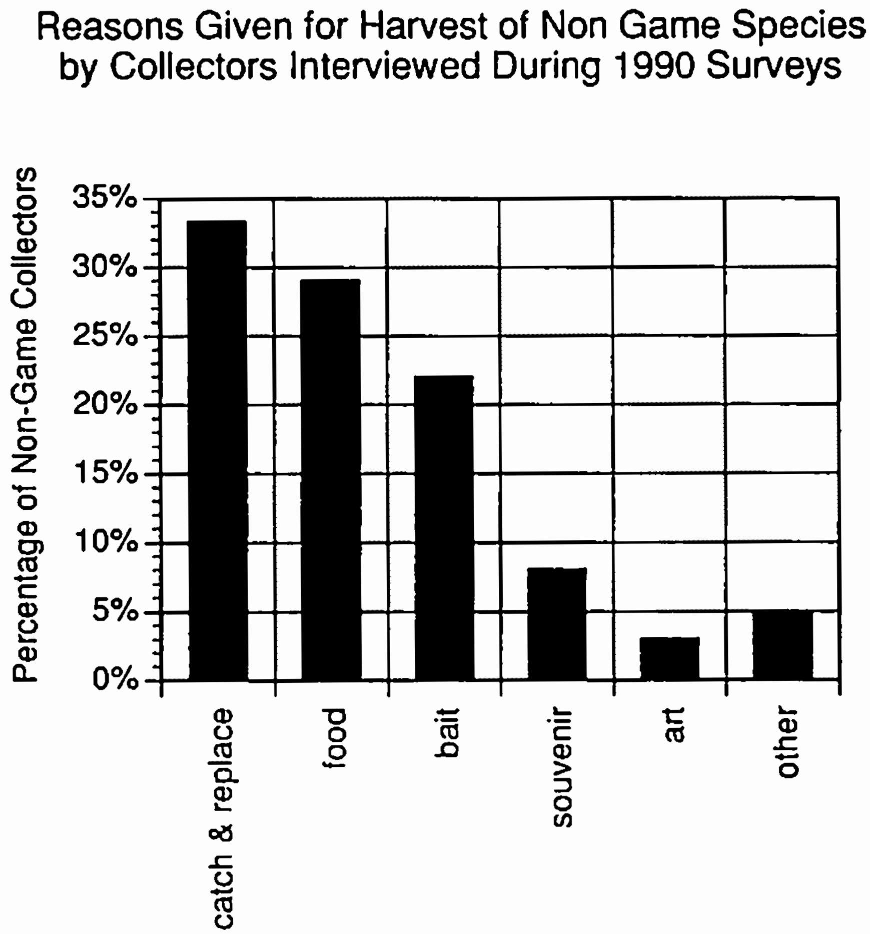


FIGURE 3. Reasons given for the harvest of nongame species by collectors (n= 315).

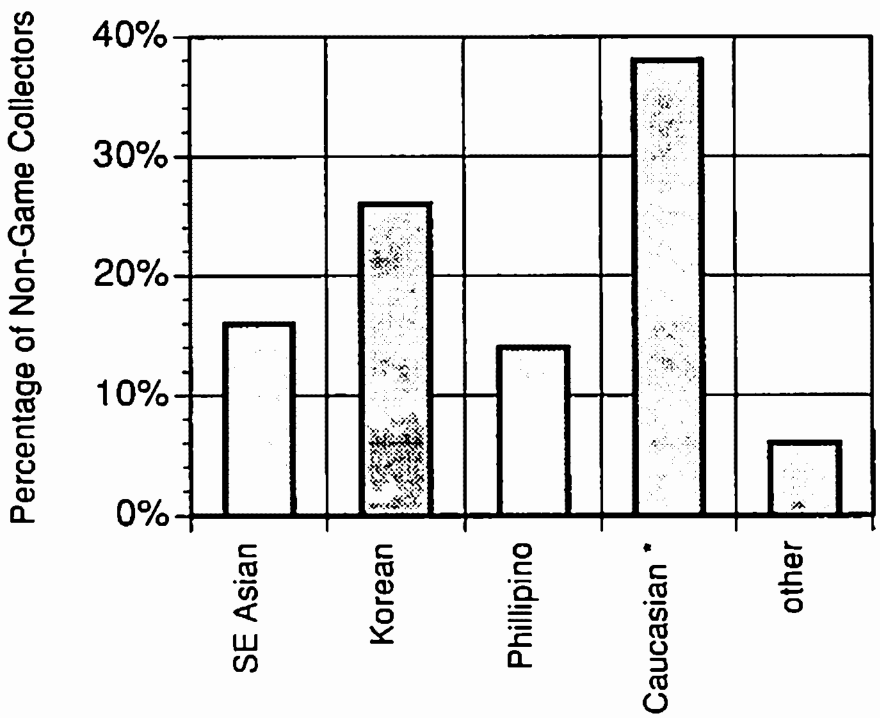


Figure 4. Ethnic heritage of nongame harvesters collecting for food and bait(n= 178).

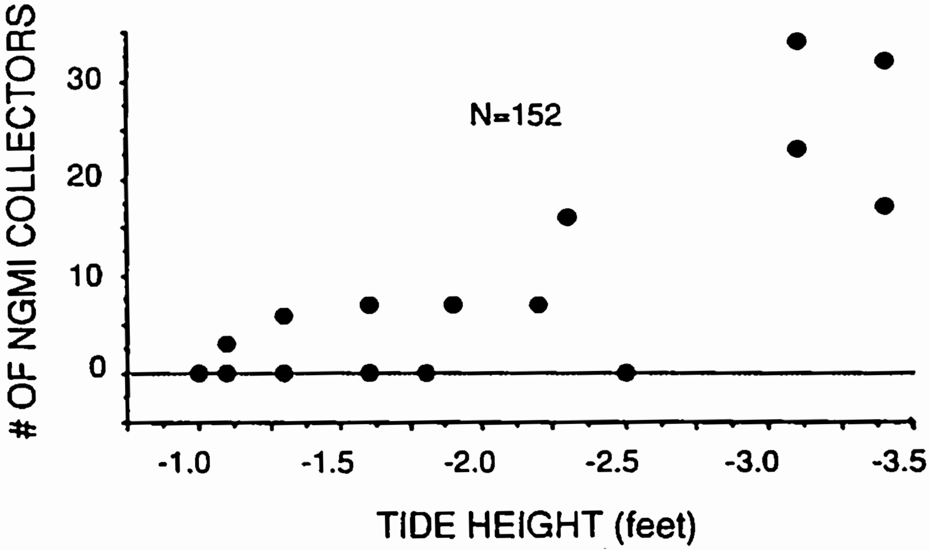


FIGURE 5. The number of NGMI collectors increases with decreasing tidal height (from Rosario Beach Bucket Survey results (p=.001. R2=0.66).

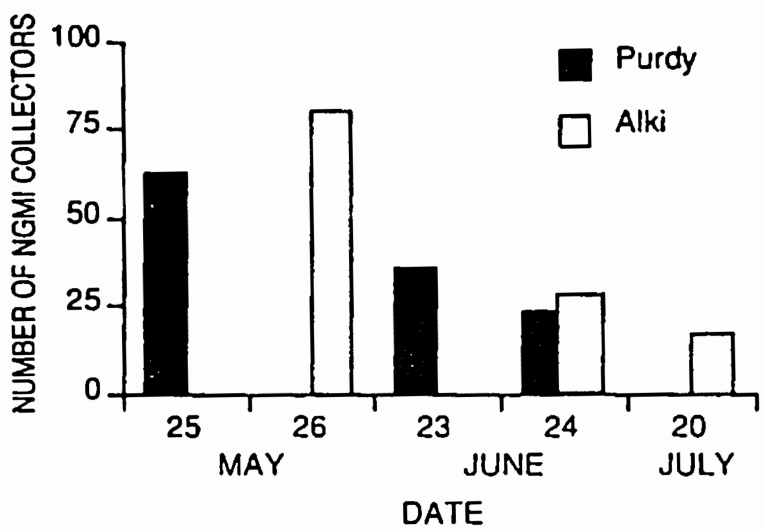


FIGURE 6. The number of NGMI collectors during days with comparable tidal heights decreases as the season progresses (from nadir counts).

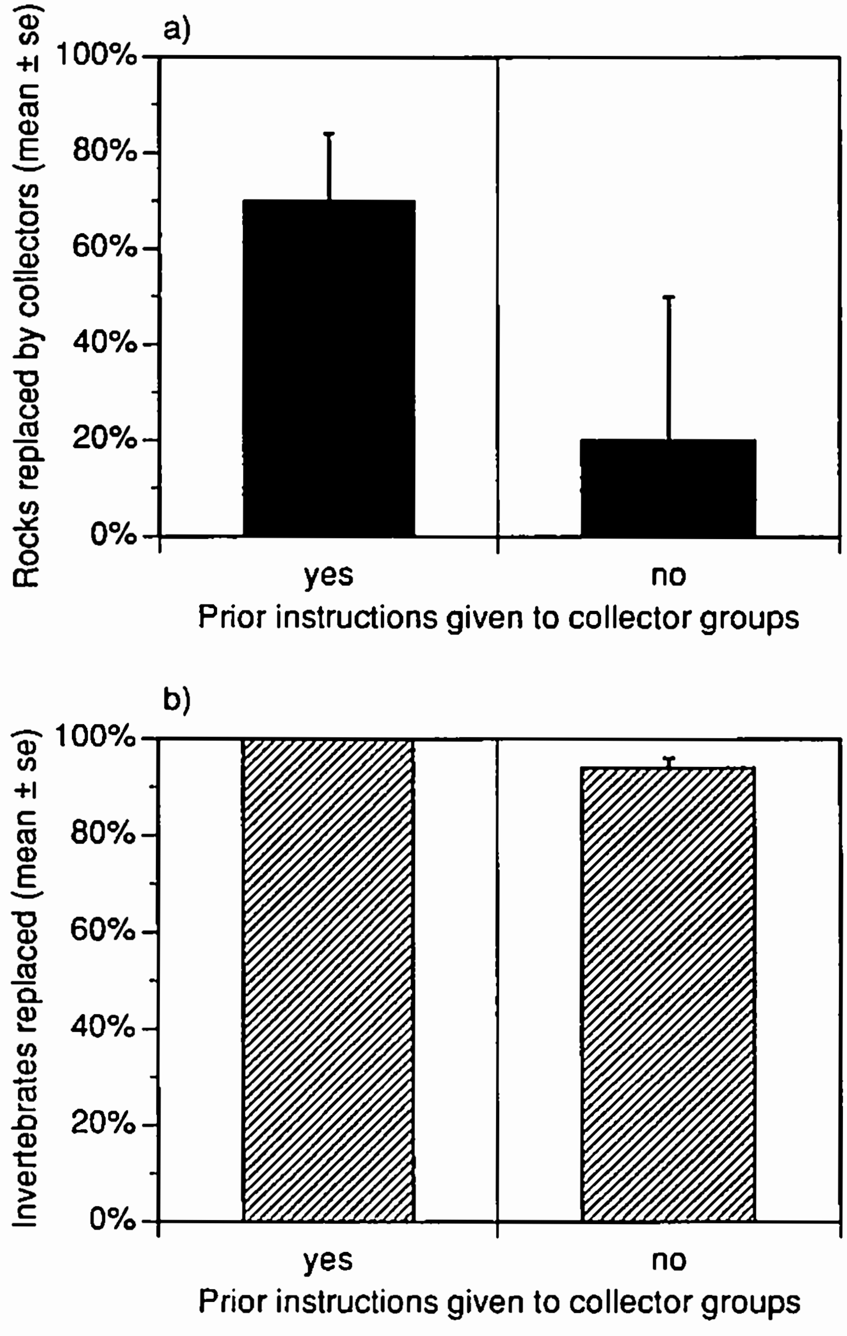


FIGURE 7. Prior instructions to replace over-turned rocks and invertebrates given to groups of NGMI collectors by their leaders had a positive effect on collector behavior. a) The mean percentage of rocks replaced by 8 groups receiving instructions was significantly higher than for 4 groups not so instructed (1-tailed t-test, $p = 0.03$, percentages arcsin transformed). b) Although the difference in invertebrate replacement was significant (1-tailed t-test, $p = 0.03$), replacement was high in all cases.

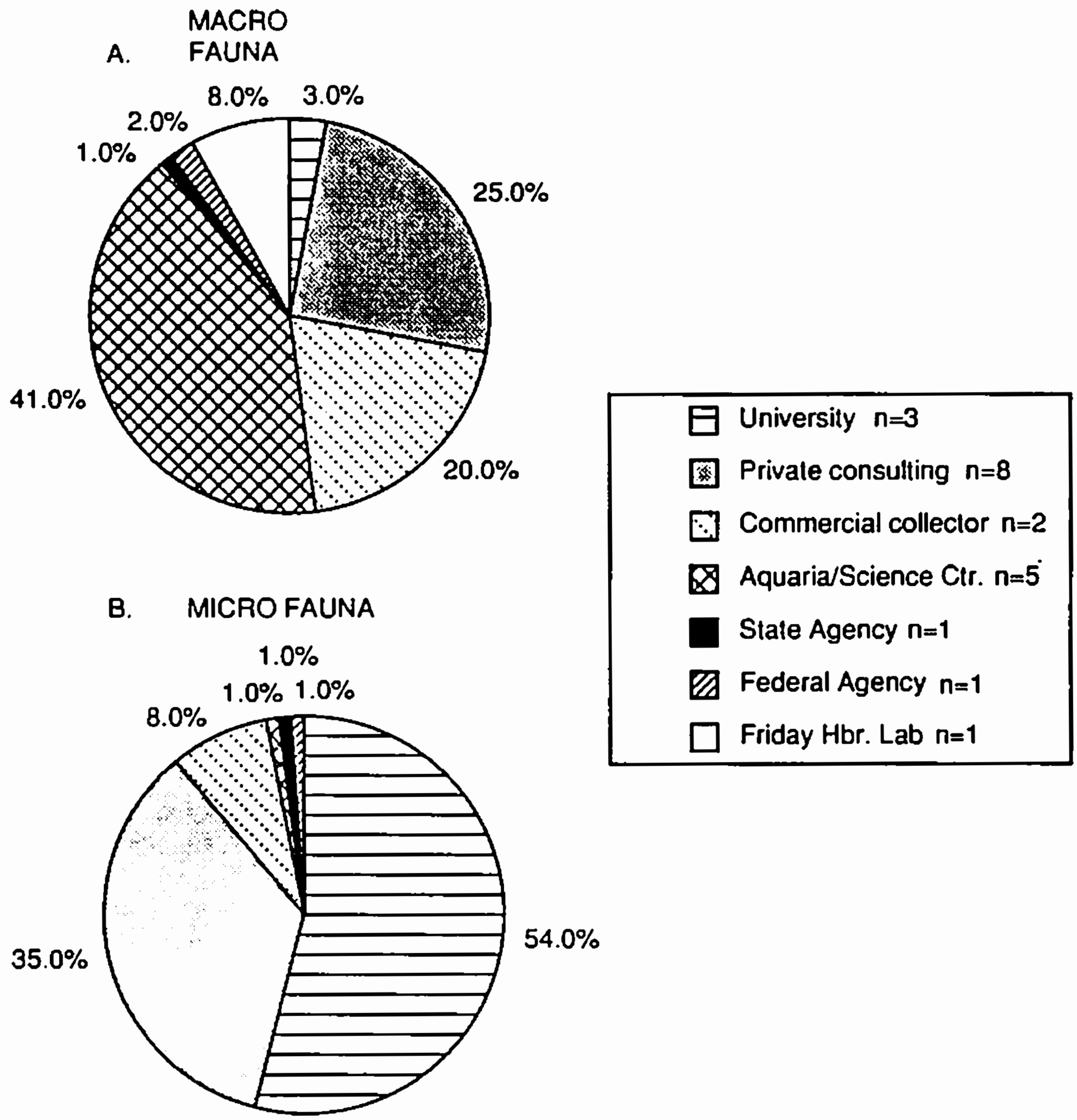


FIGURE 8. A. Aquaria and science centers collected 41% of NGMI macrofauna (species with adult length > 10mm). Private consulting firms and commercial collectors harvested 25% and 20%, respectively (from 1990 WDW research permits, organization collection logs, and phone interviews). B. The most NGMI microfauna (species with adult length ≤ 10mm) were harvested by universities for research (54%). Polychaetes were the species most collected. Private consulting firms collected 35% of NGMI microfauna, primarily the amphipod, *Rhepoxynius abronius* (from 1990 WDW research permits, organization collecting logs and phone interviews).

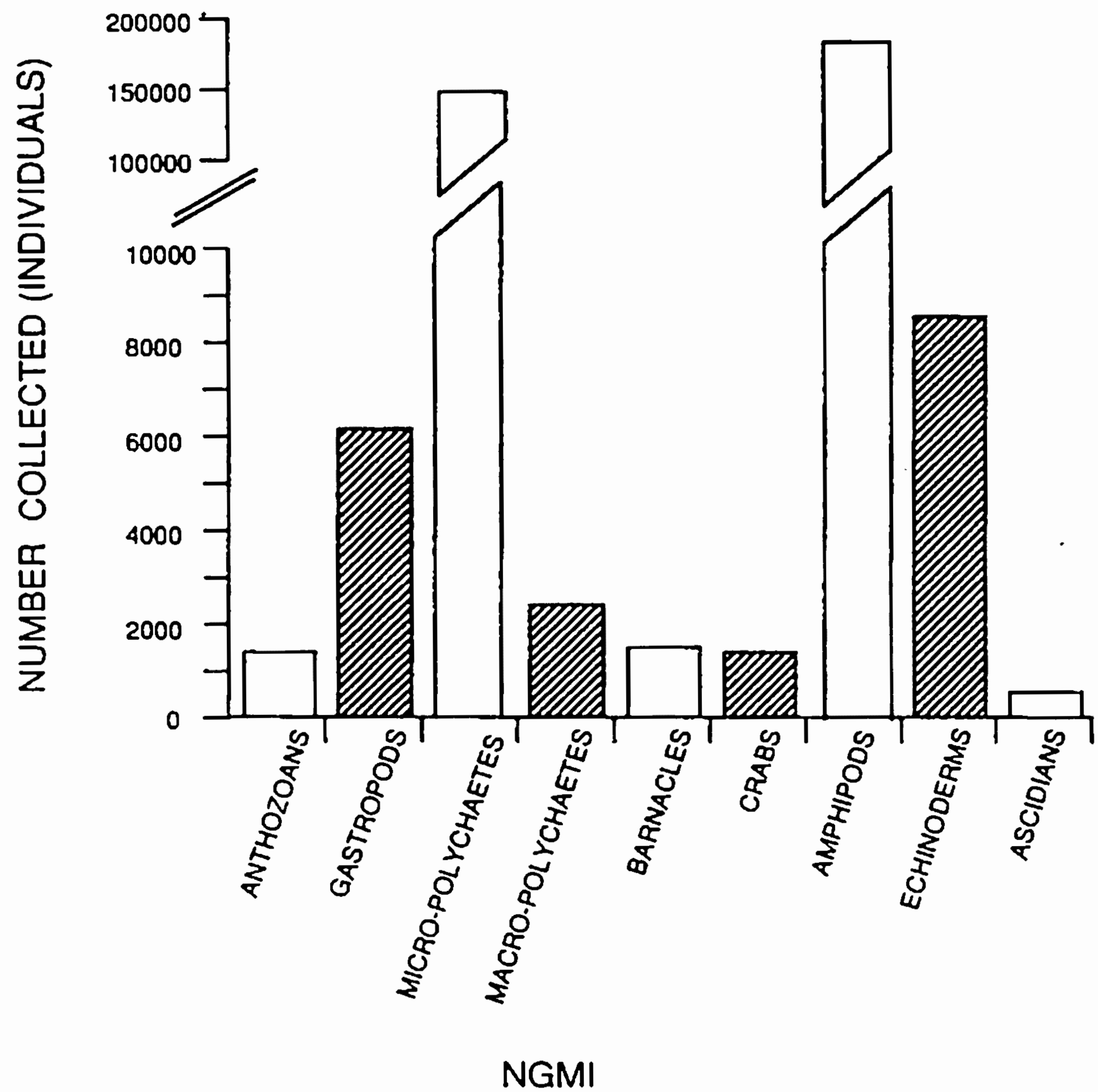


FIGURE 9. Numbers of NGMI species collected by aquaria, science centers, biological consulting firms, commercial collectors, educational institutions, Friday Harbor Labs., and state and federal agencies (from 1990 WDW research permits, organization collecting logs, and phone interviews).

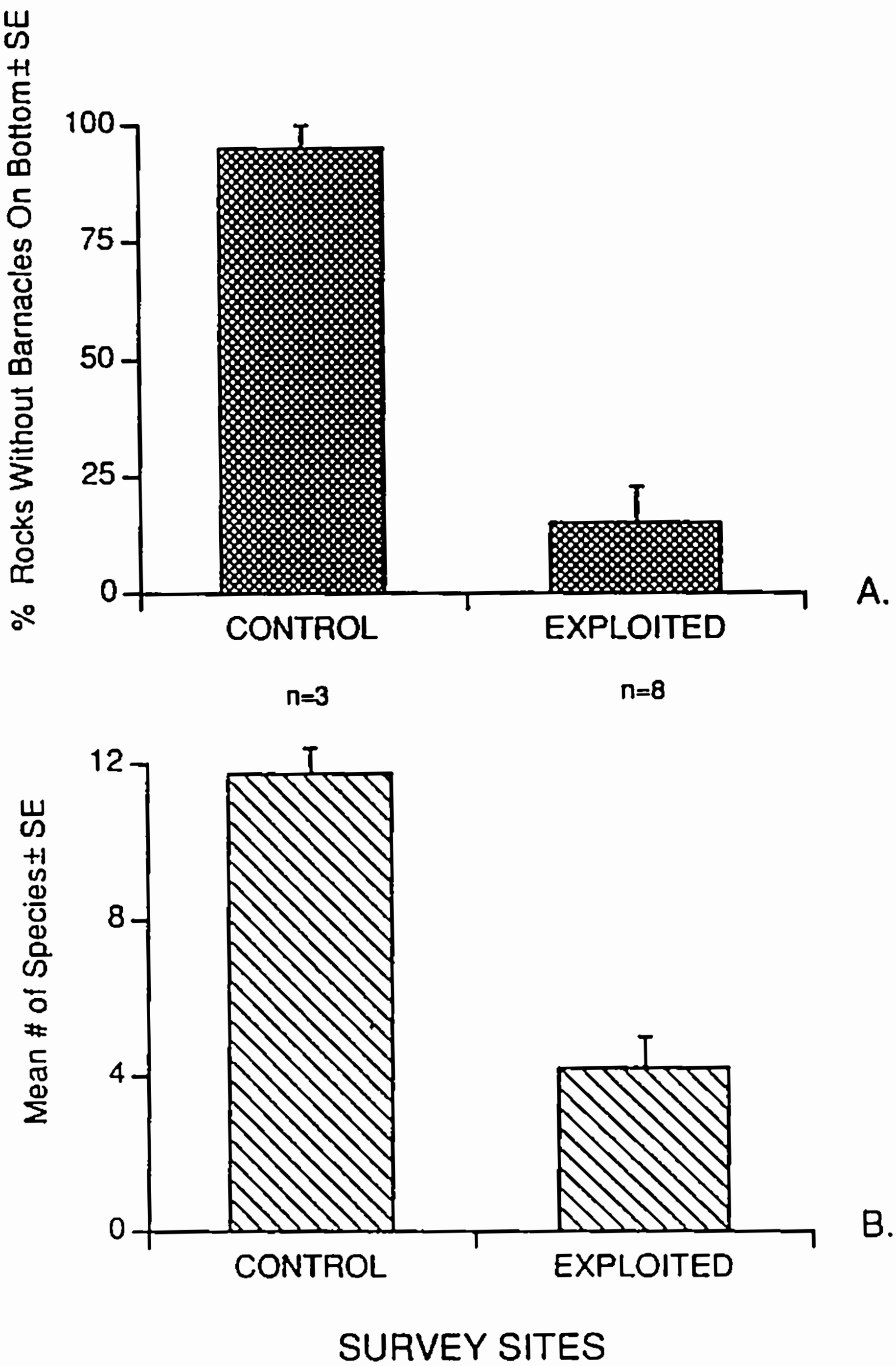


FIGURE 10. A. Significantly more rocks had barnacles on their undersides at the exploited sites than at the control sites (t-test, t=5.9, p=0.001, DF=9). B. The mean number of NGMI species were significantly higher at control sites than at exploited sites (t-test, t=5.3, p=0.001, DF=9).

APPENDIX A

Marine invertebrate species classified by the Washington Department of Fisheries as foodfish or shellfish.

GROUP/SPECIES	COMMON NAME
ABALONE	
Haliotis kamtschatkana	Pinto abalone
H. rufescens	Red abalone
BARNACLES	
Pollicipes polymerus	Gooseneck barnacle
CLAMS	
Clinocardium nuttalli	Cockle
Macoma secta	Bent nose clam
Macoma spp.	
Mya arenaria	Mud clam
Panope abrupta	Geoduck
Protothaca staminea	Little neck clam
Saxidomus giganteus	Butter clam
Siliqua patula	Razor clam
Tapes philippinarum	Manila clam
Tresus capax	Horse clam
T. nuttalli	Gaper clam
Zirfaea pilsbryi	Piddock
CRAB	
Cancer magister	Dungeness crab
C. productus	Red crab
Chionoecetes tanneri	Tanner crab
MUSSEL	
Mytilus californianus	California mussel
M. edulis	Blue mussel
OCTOPUS	
Octopus dofleini	Giant Pacific octopus
OYSTER	
Crassostrea gigas	Pacific oyster
C. gigas (Kumamoto)	Kumamoto oyster
C. virginica	Eastern oyster
Ostrea lurida	Olympia oyster
O. edulis	European oyster
Ostreidae	All other oysters
SCALLOPS	
Chlamys hastata	Spiny scallop
C. rubida	Pacific pink scallop
Crassadoma gigantea	Rock scallop
Patinopecten caurinus	Weathervane scallop
SNAIL	
Polinices lewisii.	Moonsnail

SEA CUCUMBER	
Cucumaria miniata	Sea cucumber
Parastichopus californicus	Sea cucumber
SEA URCHIN	
Strongylocentrotus droebachiensis	Green urchin
S. franciscanus	Red urchin
S. purpuratus	Purple urchin
SHRIMP	
Callianassa spp.	Ghost shrimp
Pandalopsis dispar	Sidestripe shrimp
Pandalus borealis	Pink shrimp
P. danae	Coonstripe shrimp
P. hypsinotus	Coonstripe shrimp
P. goniurus	Humpy shrimp
P. jordani	Ocean pink shrimp
P. platyceros	Spot shrimp
Upogebia pugettensis	Mud shrimp
SQUID	
Loligo opalescens	Pacific coast squid
Ommastrephes bartramai	Flying squid
Onychoteuthis borealijaponica	Nail squid
Sepiodea or Teuthoidea	All other squid

APPENDIX B

Path descriptions and lengths for faunal baseline and bucket surveys on Puget Sound beaches.

BEACH	PATH LENGTH (m)	PATH DESCRIPTION
Alki		The length of the beach fronting Beach Dr. SW, from Benton Pl. SW to SW Charleston
Carkeek Park	900	The length of the park
Ebey's Landing (Fort Ebey)	500	The length of the beach access.
Edmonds State Park	200	The pilings near the parking lot S 200 m.
Fort Flagler Historic Park	1000	From the pilings on the NW side of the spit at the Fort Flagler Historic Park campground, continuing SW towards the grassy headlands, then NE towards the boat ramp
Golden Gardens Park	900	The length of the park
Manchester beach	300	The length of the park
Mukilteo North	600	The public access NE of the ferry dock. NE from the fuel tanks to the rocky headland
Mukilteo State Park (South)	200	The boat ramp S to the end of the park
Picnic Point	600	The park access N to the pilings
Purdy	1200	The length of the public access on the shore extending W of Burly Lagoon.
Rosario State Beach	300	The length of the beach
Saltwater State Park	600	The length of the park
Seahurst Park	1500	The length of the park
Steilacoom	5000	Salter's Point S to Tatsolo Point
Titlow Beach	900	6th Ave. public access N to private boat ramp
West Beach State Park	300	Parking lot N to rocky headland

APPENDIX C

NGMI Bucket Survey Form

NGMI BUCKET SURVEY

Page ____

Location ____ Weather ____ DOW ____

Date ____ Time ____ Tide ____ Surveyor ____

Nadir count: (total scan count of all collectorson beach at exact moment of the low tide)
Adults ____
Children ____

USES
Bait - B
Food - F
Aquaria - A
Bio Supply - BS
Research - R
School-So
Souvenir - S
To sell - P
Destroy - D
Collect/replace - CR
Art - AR

DISTURBANCE
Digging - D
Feeling w/feet - F
Raking - R
Rock turning - T
Other - specify

Nationality
Latino - L
Cambodian - C
Korean - K
Vietnamese - V
Hmong - H
Japane
Philippi
Asian -
Non-Eng
Speakin

Party #	# in party Adlt / chld	Species Collected	Amt Ind - I Gal - G Kg - K	How long today?	Are they done?	Use	How often this beach?	Where else they collect?	Other spp. they looking for?	Disturbance

APPENDIX D

Surveyor ______________________

NGMI SCHOOL SURVEY FORM

Location Date Time

School name School Location Grade

1) How often collect? ______________________
2) Where else? ______________________
3) Number of students ______________________
4) Students received prior orientation about not taking inverts. ☐
5) Students received prior instructions about returning turned rocks ☐

Rock Replacement: Tally replaced ______________________
Tally not replaced ______________________

6) What species have they been directed to collect:? For what purpose? ______________________

Species Collected	Running Tally **To Be Replaced**	Running Tally **To Take Home or School**

APPENDIX E

Variables used to calculate NGMI harvest estimates

E = nadir collector count (adults + children)
a_n = number of NGMI collectors surveyed
a_t = number of all collectors surveyed
c = actual recorded catch of a given NGMI
m = number of minutes a collector had been harvesting when interviewed
$h = \sum a_n \cdot m$ = observed harvest pressure
$r = c/h$ = harvest rate for given NGMI
$En = E \cdot (a_n/a_t)$ = proportion of NGMI harvesters on beach
T = harvest duration = number of harvestable hours (i.e. tide below 0.0 ft)
$Hp = En \cdot T$ = harvest pressure
$Cd = H \cdot r = H \cdot (c/h)$ = days harvest for a given NGMI
Pn = number of NGMI parties on beach (trips)

For each day and beach

harvest rate = c/h
non-game harvesters = $En = E \cdot (a_n/a_t)$
harvest rate = c/h
harvest pressure = $Hp = En \cdot T$
days harvest = $C = Hp \cdot (c/h)$

For each stratum (week day, and weekend or holiday) per beach for days sampled

$i = 1....n$ sample days in stratum
P_i = NGMI collector trips for the i^{th} sample day
H_i = NGMI harvest pressure for the i^{th} sample day
C_i = NGMI catch of a given category for the i^{th} sample day
N = number of harvestable days in the stratum (days with tides < 0.0 ft)

means calculated as:

$$\hat{X}_i = \frac{\sum_{i=1}^{n} X_i}{n}$$

variances of means calculated as:

$$\mathrm{Var}\,(\hat{X}_i) = \frac{N-n}{n} \cdot \frac{\sum_{i=1}^{n} (X_i - \hat{X}_i)}{(n-1) \cdot n}$$

Stratum totals for all harvestable days during the entire season

means calculated as:

$$\hat{X} = N \cdot \hat{X}_i$$

variances of means calculated as:

$$\mathrm{Var}\,(\hat{X}) = N^2\,\mathrm{Var}\,(\hat{X}_i)$$

Annual totals for a beach were calculated by summing the estimated means for both strata. Variances are also additive. Standard deviation is the square root of the variance.

APPENDIX F

Results of phone survey to Seattle area public school teachers ,June 1990, and estimates of the extent of school children traffic on Puget Sound beaches.

DISTRICT	GRADE	# OF STUDENTS IN GRADE	# OF STUDENTS SURVEYED	#TO GO TO BEACH	% OF STUDENT SURVEY	PROJECTED TOTAL TO BEACH
Edmonds	K-6	9300	2530	50	1.9	177
	7-8	2600	1274	70	5.5	143
	9-12	5098	1905	276	14.5	739
Highline	K-6	7837	5956	709	11.9	933
	7-8	2040	1280	0	0	0
	9-12	3728	3486	21	.6	22
Mercer Is.	k-6	1754	962	100	10.4	182
	7-8	510	0	0	0	0
	9-12	1024	1024	0	0	0
Northshore	K-6	9907	3020	310	10.3	1020
	7-8	2649	0	0	0	0
	9-12	4669	0	0	0	0
Seattle Public	K-6	25548	2246	511	22.8	5813
	9-12	10720	800	100	12.5	1340
TOTALS		87384	24483	2147		10369

APPENDIX G

Numbers of NGMI species collected by user-groups determined from evaluation of 1990 WDW research permits, organization collecting logs and phone interviews of organization representatives. Groups include: Univerities (Univ), Private consulting laboratories (Cnslt Labs), Commercial collectors (Com. Coll.), Aquaria and Science centers (Aquaria), State agencies (State Agn.), Federal agencies (Fed. Agn.), and Friday Harbor Labs (FHL).

SPECIES	Univ.	Cnslt Labs	Com. Coll.	Aquaria	State Agn.	Fed. Agn.	FHL	Total
SPONGES								
Sponge spp.				71			8	79
Cliona celata				2				2
Halicondria panicea		5	20					25
Isodictya quasinoesis				5				5
Mycale adhaerens				2				2
Syringella celata				2				2
SCYPHOZOA								0
Scyphozoa spp.				2				2
Haloquistes sp.	5							5
SEA PENS								0
Ptilosarcus gurneyi			46	430			58	534
SEA Whips								0
Stylatula elongata				15			7	22
SOFT CORAL								0
Gersemia rubiformis				1				1
SEA ANEMONES								0
Anthopleura elegantissima		5	82	2				89
A. xanthogrammica		15	65	25				105
Cribrinopsis fernaldi		5	15	12				32
Epiactis prolifera			4	6				10
Metridium senile		5	65	200			11	281
Pachycerianthus sp.							1	1
Stomphia didemon		5	25	55			1	86
Tealia spp.			130	30			2	162
Urticina spp				70				70
CHITONS								0
Chryptochiton stelleri			20	80			1	101
Katharina tunicata				10			1	11
Mopalia spp.	5		55	20				80
Tonicella spp.		15	15	35				65
LIMPETS								0
Limpet spp.	10		35	3500			1	3546
Diodora aspera			10	110				120
GASTROPODS								0
Snail spp.				30			44	74
Calliostoma annulatum			20	150			1	171
Ceratostoma foliatum			10	20			1	31
Fusitriton oregonensis			35	50				85

Nucella spp.			80	20				100
Tegula sp.				1000				1000
NUDIBRANCHS								0
Anisodoris nobilis				20				20
Archidoris odhneri				25				25
Armina californica			40	35			15	90
Coryphella sp.				30				30
Dendronotis iris				10			15	25
Diaulula sandiegensis				10				10
Dirona albalineata				100				100
Discodoris heathi				5				5
Hermissenda crassicornis				20				20
Melibe leonina			10					10
Triopha spp.			20					20
Tritonia							562	562
ANNELIDS								0
Polychaete spp.	8		1500	70			48	1626
Eudistylia vancouveri		700	15	10				725
Hetermastus filiformes	50000							50000
Polydora kempi	50000							50000
Streblospio benedicti	50000							50000
BARNACLES								0
Balanus glandula				160				160
B. nubilus			550	700			127	1377
Tanaid sp.	50000							
AMPHIPODS								0
Ampipod spp.		30000	10000	3000				43000
Rhepoxynius abronius		100000	20000		5000	2000		127000
CRABS								0
Cancer gracilis				20			67	87
Hapalogaster mertensii				10				10
Hemigrapsus oregonensis				20			1	21
Hemigrapsus nudus				300				300
Oregonia gracilis	10		120	25			75	230
Pagarus/Ellasochirus spp	10		120	70			145	345
Petrolisthes eriomerus			2	5			12	19
Pugettia spp.	4		110	75			7	196
Scyra acutifrons		10	1	50			5	66
Spider crab spp.	30						30	60
Telmessus cheiragonus				5				5
BRYOZOANS								0
Heteropora magna				10				10
BRACHIOPODS								0
Brachiopod spp.	5						35	40
SEA STARS								0
Cribrinopsis fernaldi	1							1
Crossaster papposus	1						7	8
Dermasterias imbricata	1		65	30				96
Evasterias troschelii	1		25	100			7	133
Henricia leviascula	16		40	170			11	237

Hippasteria spinosa	1		105	55				161
Leptasterias hexactis				3				3
Luidia foliolata	1		20	1			190	212
Mediaster aequalis	1		55	85			13	154
Orthasterias keohleri	1		5	100				106
Pisaster spp.	1	10	45	45			7	108
Pteraster sp.	3			1			8	12
Pycnopodia helianthoides	4	10	5	75			60	154
Solaster spp.	6		190	60				256
BRITTLE STARS								0
Gorgonocephalus sp.							2	2
G. eucnemis				1				1
Ophioroid spp.		10	4	15			77	106
SAND DOLLARS								0
Dendraster abronius	550	4800		24	200			5574
D. excentricus				510		300		810
SEA CUCUMBERS								0
Cucumaria sp.						21		21
Cucumaria piperata	15		65	5				85
Eupentacta quinquesimita	1		100	15		20		136
Parastichopus californicus	1					1		2
Psolus chitonoides	1		15	5		2		23
Stichopus sp.						56		56
ASCIDIANS								0
Ascidian spp.			460	75		3		538
Total Macro fauna	693	5595	4419	9115	200	403	1663	22088
Total Micro fauna	200000	130000	30000	3000	5000	2000	0	370000

APPENDIX H

BASELINE FAUNAL SURVEYS - PROTECTED (CONTROL) SITES

Site/Species	DENSITY/M^2 ROCK			SIZE (mm)		

MCNEIL ISLAND
Transect Height: -1.6' below MLLW.

	mean	SD	n	mean	SD	n
Anthopleura	15	16	22			
Mopalia	2	4	25	30	8	39
Tonicella	2	7	25	31	9	4
Nucella lamellosa	8	15	25	42	11	32
Pododesmus cepio	33	33	25	45	5	5
Terebellid worm	13	14	25			
Hemigrapsus nudus	46	41	25	30	8	39
Petrolisthes	20	30	25	21	2	8
Sea stars: *Leptasterias hexactis, Pisaster ochraceus*	1	3	25	420	22	8
Cucumaria	2	4	25			
Midshipmen	4	4	25			

SEAHURST (CONTROL)
Transect Height: 1.0' above MLLW.

	mean	SD	n	mean	SD	n
Mopalia	5	10	29	66	13	23
Nucella lamellosa	61	61	29	27	11	152
N. emarginata	4	10	29	24	4	60
Pododesmus cepio	.7	4	29			
Terebellid worm	2	9	29			
Idotea	5	12	29			
Hemigrapsus spp.	39	38	29	19	5	54
Hermit crab	14	25	29			
Pugettia spp.	.1	.7	29			
Sea star spp.	.1	.4	29			

Washington Department of Wildlife

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wildlife and people—
now and in the
future

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