

The recent status of sea cucumber fisheries in the continental United States of America

Andrew W. Bruckner¹

Introduction

Sea cucumber fisheries occur in waters of the United States off the Pacific coast states of California, Oregon, Washington and Alaska, and the Atlantic coast state of Maine. In the Pacific, commercial harvest focuses on two species in the family Stichopodidae, *Parastichopus californicus* (giant red sea cucumber) and *P. parvimensis* (warty sea cucumber). In the Atlantic, commercial fisheries target a single species in the family Cucumariidae, *Cucumaria frondosa*. Commercial fisheries in the US were first established in Washington state (1971), followed by California (1978), Alaska (1981), Maine (1988), and Oregon (1993). Sea cucumbers are selectively collected by hand using scuba or hookah, and non-selectively harvested with bottom trawls, scallop chain sweeps and urchin drag gear. Sea cucumber fish-

eries are managed by each state, using a variety of management measures such as permitting and licensing requirements, spatial and temporal closures, harvest quotas, seasonal fishing periods, and gear restrictions (Table 1).

Maine currently has the largest sea cucumber fishery (based on wet weight), followed by Alaska, Washington and California, respectively; minimal harvest occurs in Oregon. Total harvests for California and Washington peaked in 1991 (2144 metric tonnes [t]) and have subsequently declined to 500–600 t per year (Fig. 1). According to FAO statistics, the total fisheries production for US temperate sea cucumber fisheries between 1992 and 2001 was 18,127 t, with a maximum harvest of 4583 t in 2000 (Table 2). Most sea cucumbers are exported to Hong Kong, Chinese Taipei, mainland China and Korea, with limited consumption in

Table 1. Controls and enforcement measures for sea cucumber fisheries in US temperate waters.

Location	Licensing	Reporting	Validation
Alaska, USA	Divers registered and permitted.	Dive/harvest logbook with date, location (GPS), depth, bottom time, quantity.	Divers can only obtain permits for urchins or sea cucumbers but not both.
Washington, USA	Limited entry; 190 divers in 2000.	Logbooks with daily reporting of catch to avoid exceeding quota.	Must submit logbooks every month with data on date, depth location and amount (number and weight) collected.
Oregon, USA	Licenses issued up to 2003, with only two divers requesting a license.	Fish receiving tickets (dock ticket) required from sea cucumber dealers with fisherman's name, location, date and amount.	Cucumbers are listed under developmental fisheries species list category B. As of 2004 the fishery no longer requires a permit.
California, USA	Separate annual permits for each gear type: In 2004 95 dive permits and 24 sea cucumber trawl permits were issued.	Dive and trawl fisheries target different species and areas; Trawl fishery near port of Los Angeles; dive fishery near Santa Barbara.	Limit permits by requiring a minimum landing of 50 lbs during the previous year. Permits can be transferred if the permit holder held a valid sea cucumber permit for any four permit years and landed at least 100 pounds of sea cucumbers in each of those permit years.
Maine, USA	In 2004, 10 endorsements.	Harvester Logbooks.	Limit licenses to fishermen that landed >250,000 lbs in a previous year. No incidental take allowed, only take through targeted, licensed fishery.

1. Office of Habitat Conservation, Coral Reef Conservation Program, NOAA Fisheries, 1315 East West Highway, Silver Spring, MD 20910 USA. Email: Andy.bruckner@noaa.gov

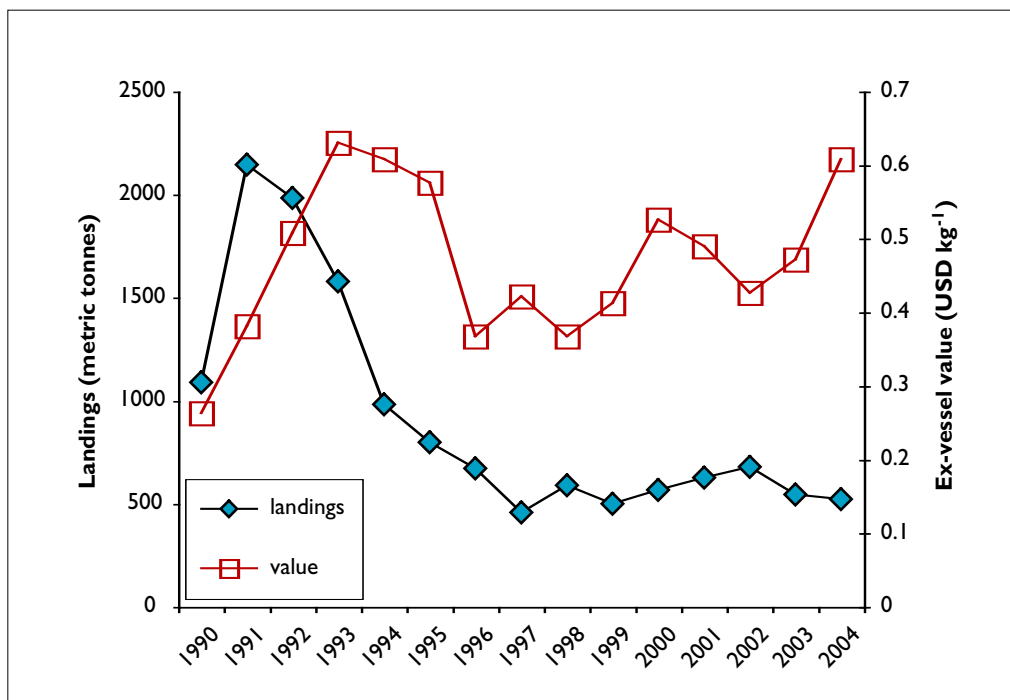


Figure 1. Sea cucumber landings (t) and ex-vessel value (USD kg⁻¹) between 1990 and 2004 for California and Washington.

Table 2. Sea cucumber production and export. Production is in metric tonnes (t) (FAO FishStat Plus v. 2.3; Hong Kong SAR import statistics).

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
U.S. production	<0.5	481	472	2141	729	1779	-	2406	3732	4583	1804
Hong Kong imports										181.57	89.74

Table 3. Recent landings (t) and value (USD ,000) of sea cucumbers in California.
* In 2001 and 2002 species of *Parastichopus* were not separated.
Source: California Department of Fish and Game (CDFG) 2005.

	2001	2002	2003
Red sea cucumbers (t)	*	*	132.6
Warty sea cucumbers (t)	*	*	209.2
Sea cucumbers total value (USD ,000)	325.5	429.5	344.1

Table 4. Sea cucumbers landings (kg) and number of permits issued in Oregon, 1995–2003. As of 2004, permits are no longer required.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Landings (kg)	0	0	3295	0	3.28	132	15.9	0	312	120.6
Harvesters			5		2	1	2		2	
Permits issued	15	3	7	9	2	7	8	4	2	0

Chinese markets in the US; a small portion of the processed product is also used locally for nutritional supplements and arthritis treatments.

US sea cucumber fisheries

California

A commercial fishery for *P. californicus* and *P. parvimensis* was established in 1978 using scuba diving and trawls. Most trawl effort is concentrated in southern California, and collection is by hand using scuba in northern California. Until 1997 about 75% of the annual catch was from the southern California trawl fishery. Declines in harvest from southern California have occurred in recent years, partially due to prosecution of illegal trawl fishers, which reduced the total number of trawl fishermen. Beginning in 1997, divers who held sea urchin and abalone permits shifted their efforts to sea cucumbers. The dive fishery has increased substantially, and now accounts for 80% of the total harvest (Rogers-Bennett and Ono 2001).

Annual landings remained under 40,000 kg until 1982, when the principal trawl areas shifted from Los Angeles area ports to the Santa Barbara Channel. Currently, most fishing is in the Los Angeles and Santa Barbara areas, with limited harvest off San Diego and Bodega Bay. Between 1983 and 1990 annual landings fluctuated between about 20,000 and 60,000 kg. In 1991, over 261,871 kg were harvested. Combined trawl and dive harvest peaked in 1996 at 380,703 kg with an ex-vessel value of USD 582,370 (Rogers-Bennett and Ono 2001). Although there are fewer dive and trawl permits in recent years, the sea cucumber harvest has remained at levels close to that reported in 1996 (Table 3).

Since 1992–1993, a special permit has been required for harvesting sea cucumber, at a cost of USD 250 per year. Permit recipients must have landed a minimum of 20 kg during the previous four-year period. In 1997, separate permits were issued for each gear type, with a limit on the total number of permits issued. A maximum of 111 dive permits and 36 trawl permits were issued in 1997, and this declined to 95 dive permits and 24 trawl permits in 2004. There are no restrictions on catch, but trawling is prohibited in the Trawl Rockfish Conservation Areas (water from 30 fathoms to 150–250 fathoms (depending on latitude) along the mainland coast, shoreline to 200 fathoms around most islands, except the Farallon Islands, where the fishery is closed from the shoreline to 10 fathoms) (CDF&G, 2005). Other trawl fisheries have a total trip limit of 136 kg of bycatch, which includes sea cucumbers.

Oregon

Oregon's sea cucumber fishery began in 1993. The primary target is *P. californicus*, with most collection done by hand using dive gear. Harvest by trawl was also allowed, but required an experimental gear permit (McCrae 1994). Oregon Department of Fish and Wildlife placed sea cucumbers within the Developmental Fisheries Program, which was developed in 1993 to allow for the controlled development of new commercial fisheries. Under the first year of the program 44 permits were issued, but only 9 divers were active, landing 2335 kg of sea cucumbers. In 1994, 22 divers landed 4777 kg of sea cucumber. Between 1995 and 2004, there was little or no harvest in Oregon waters, with exception of 1997 (Table 4).

Permits were issued to sea cucumber fishermen until 2003, when sea cucumbers were moved to category B of the Developmental Fisheries Program species list, which includes those species with less potential for a viable fishery. For 2004 and beyond, sea cucumber harvest no longer requires a developmental fishery permit (McCrae pers. comm.).

Washington

The Washington State sea cucumber fishery is based on one managed species, *P. californicus*, with commercial and tribal fisheries concentrated around the San Juan Islands and in Port Angeles. Commercial harvest primarily involves hand collection using scuba or hookah, with lower levels of harvest by an experimental trawl fishery. Sea cucumbers may also be collected while diving for personal use, with a daily limit of 10 animals. An additional 13 non-classified sea cucumber species are also collected at low levels in Washington State waters for research and public aquaria under Washington Department of Fish and Wildlife (WDFW) Scientific Collecting permits. The average statewide CPUE has increased since 1996 and has reached a historic high, possibly as a result of a smaller, more efficient fleet. There are currently 46 licensed commercial divers, with a license reduction program initiated in 2002, with the goal of reducing the total number of licenses to 25.

The sea cucumber fishery was established in 1971 and occurred without restrictions until 1987. In the early and mid-1980s commercial harvest was relatively low (125–181 t year⁻¹) and the value was low (USD 0.06–0.13 kg⁻¹). The total harvest began to increase in 1988 (952 t) and peaked in 1992 (1880 t). This increase was associated with an increase in the value of sea cucumber (from USD 0.21 kg⁻¹ in 1988 to USD 0.87 kg⁻¹ in 1993). However, the dramatic increase in harvest increased concerns of the po-

tential for overexploitation and a seasonal harvest and specific harvest districts were subsequently adopted, along with the adoption of a total harvest quota in 1994.

Current management measures for the Washington State sea cucumber fishery include closed seasons, spatial closures, licensing of collectors, and an annual quota. Seven area closures for the dive fishery have been established in the current management plan, including two that are closed for human health reasons and a prohibition on trawling in shrimp areas. Other regulations for the trawl fishery include 1) a ban on trawling in waters less than about 20 m deep; 2) temporal closures during soft-shell Dungeness crab (reproductive) periods; 3) specific fishing locations; and 4) restrictions on gear type and size, including maximum beam width for beam trawl gear and minimum mesh size for otter trawl gear. The commercial dive fishery is open year round.

Harvesting in Washington State occurs under a cooperative management agreement with treaty tribes. There are five management regions in Puget Sound, with about 50% of the total quota allocated for state harvest and 50% tribal harvest. The annual statewide harvest guideline (1997–2002) was 427,690 kg, with a total estimated available commercial biomass of 5.58 million kg. As a precautionary approach, the 2003–2004 quota has been reduced by 15% of that calculated for 1997 until more recent biomass estimates are completed (Table 5). The quota has been determined using the Schaefer (1954) surplus production model based on estimates of biomass from catch-effort data, video surveys, and dive surveys (Bradbury 1994).

Fish receiving tickets are submitted to Washington State Department of Fish and Wildlife after each fishing trip. These data are used to determine when the annual tribal and state commercial harvest quota is reached. Fishermen also submit monthly harvest logs that include the date, vessel name or

boat registration number, location fished, pounds landed, average depth of harvest, number of divers, and total diver hours spent fishing. Based on submitted logbooks, annual landings of cucumbers currently have an ex-vessel value of about USD 1 million.

Alaska

Sea cucumbers were used as a traditional food source and for subsistence along the northwest coast, including south Alaska since at least 1804. Harvest occurred primarily in the spring, summer and fall during minus tides, either from shore or boat in shallow waters, using a pole (called a *yein* or *yaanu* stick, which is about 2.5 m in length with a cross stick attached at one end; Lawrence 1977) to lift sea cucumbers from behind rocks or from eelgrass beds. Total subsistence harvest during the 1980s varied between communities with a maximum annual harvest of 4386 kg harvested by one community, with up to 51% of the households in an individual community involved in the fishery (Mathews et al. 1990).

The commercial sea cucumber fishery for *P. californicus* began in 1981 in Southeast Alaska as an experimental fishery, and in 1987 around Kodiak Island. One or two permits were issued per year between 1981 and 1986, with only one vessel reporting landings. Sea cucumbers are collected by hand using scuba or hookah, typically at depths of 3–20 m, with no restrictions on the use of mixed gases or saturation diving. Fishermen historically used small skiffs and operated as a day fishery. There has also been a recent increase in the use of larger vessels with two divers and a crewman and living quarters, which have extended the range and duration of fishing trips.

The dive fishery in both locations was initially based only on a permit system, but was closed in May 1990, to allow resource management agencies sufficient time to evaluate the status of sea cucumber re-

sources and fishing pressure, and develop a management plan. This plan relies on a quota developed based on historic production, fisheries performance, and biannual survey data of population biomass with a total harvest rate of 6%. The harvest rate is estimated to be 50% of maximum sustainable yield (MSY), calculated using a surplus production model that incorporates 1) an estimate of virgin population size; 2) a reduction of the quota to 50% of the harvest rate derived from the model; and 3) with

Table 5. Harvest guidelines for sea cucumbers in Washington (Anonymous 2003).

Management Region	2003–2004 harvestable surplus (kg)
San Juan	295,372
Strait of Juan de Fuca	70,755
Central Puget Sound (26C)	17,280
Central Puget Sound (remaining areas)	906
Hood Canal	3,084
South Puget Sound	30,840
TOTAL	372,055

Table 6a. Total landings of sea cucumbers (t), fishing effort and landed value for Kodiak Island in Alaska, 1993–2001. Source: Alaska Department of Fish and Game (ADF&G) Preliminary Alaska Commercial Shellfish Catches and Ex-vessel Values

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Landings (t)	256.1	187.6	65.8	73.7	60	64.6	52.7	52.7	69.2	77.1	63.5	58.9
No landings	487	269	60	93	65	55	36	56	73	*	*	*
Permits issued	50	86	21	31	26	16	19	20	18	*	*	*
Value (USD kg ⁻¹)	0.42	0.54	0.57	0.57	0.53	0.54	0.54	0.68	0.57	0.57	0.73	0.86

* data unavailable

another 30% reduction to account for field sampling variability. In addition, there is no allowable harvest in areas with biomass estimates below a threshold of 1 kg m⁻¹ of shoreline (Woodby et al. 1993).

The Southeast Alaska Sea Cucumber Commercial Fisheries Management plan was completed in October 1990. The management plan established 18 areas closed to fishing and annual guideline harvest levels of 6.4% of the total sea cucumber biomass taken on a 3 year rotational basis. There is also a seasonal closure (April–September), and a limit of 3 fishing days per week, and trip limits for each vessel. Fishing effort increased from 1990 to a maximum of 424 divers in 1995–1996 season. Beginning in 1996, a moratorium on the dive fishery was imposed, limiting the number of divers able to participate in the fishery to 472. To be eligible for a permit, individuals must have commercially harvested sea cucumbers at least once between 1992 and 1996. There were 235 permits issued for the 2001–2002 season (Hebert and Pritchett 2002). The quota for 2001–2002 was 646,466 kg; the actual harvest was 652,477 kg, with an estimated ex-vessel value of USD 2,517,289 (Table 6b). For the 2002–2003 season, an additional 58,000 kg were added to the quota to accommodate for collection within three newly identified collection areas (ADF&G 2005).

The commercial fishery was reopened in Kodiak in 1991 under a new management plan. The plan establishes 1) a closed season from May through September to protect spawning aggregations, and 2) fifteen large harvest refugia within the managed area. Since 1995, fishing periods have also been reduced to three days per week to allow analysis of fishing performance and monitor progress towards the established harvest guidelines (Ruccio and Jackson 2002). Starting in the 2002–2003 season, four additional areas in Kodiak district and three other areas in the Aleutian Islands were open to ex-

Table 6b. Total landings of sea cucumbers (t), number of divers and ex-vessel value in millions of USD from 1986–2001 in Southeast Alaska. Source: Alaska Department of Fish and Game (ADF&G) Preliminary Alaska Commercial Shellfish Catches and Ex-vessel Values.

Year	Landings (t)	No divers	Ex-vessel value (USD million)
1986	15.44	7	0.007
1987	29.51	11	0.014
1988	363.51	57	0.169
1989	1051.58	205	0.969
1990	364.78	143	0.472
1991	394.62	187	0.697
1992	566.82	240	0.988
1993	437.42	320	0.995
1994	599.75	261	2.361
1995	604.23	424	1.846
1996	411.32	294	1.169
1997	405.85	226	1.458
1998	478.80	219	1.636
1999	711.98	200	3.06
2000	525.44	220	2.583
2001	652.48	235	2.517
2002	743.90	*	2.870
2003	743.89	*	2.670
2004	771.11	*	2.500

*unknown

perimental fisheries, with a guideline harvest level of 2268 kg for each area (Ruccio and Jackson 2002).

Sea cucumber divers fishing in waters surrounding Kodiak are licensed and must obtain a Commercial Fisheries Entry Commission interim use permit. Fish tickets are required from fishermen, operators of commercial fishing vessels, processors and buyers; each fishing vessel with a fish ticket must provide logbooks that include coordinates of fishing areas (Ruccio and Jackson 2002). Annual quotas have been established for each area as guideline levels of harvest, currently amounting to 113,759 kg divided among Kodiak (90,719 kg) and Chignick

(23,040 kg). The number of permits reached a maximum in 1986 (86 permits), with 18 permits issued in 2001. Harvest in the 2000–2001 season amounted to 69,216 kg (Ruccio and Jackson 2002). Prices have fluctuated between USD 0.42 kg⁻¹ and 0.68 kg⁻¹ with a total landed value in 2001 of about USD 190,000.

Maine

The Maine sea cucumber fishery is a low value/high volume fishery that targets *Cucumaria frondosa*. The fishery began in 1988 with one operator, and expanded in 1994 when Asian markets for this species emerged. Fishermen use boats ranging from 12–30 m in length equipped with either scallop chain sweeps or light urchin drag gear. The gear is limited to 167 cm width and 7 m length and has a head bail constructed of less than 3.8 cm round steel stock. On a typical day, each boat harvests 70–200 t of sea cucumbers. Catch per boat per day was about 7212 kg, with an average of 16 (±5) tows per day. There are currently 16 endorsements, although only three are active (Feindel 2002).

In the mid-1990s, the industry employed 75–100 individuals who processed sea cucumbers, and 15–20 fishermen; annual harvest was 453.542–1360.512 t. Landings had increased to over 3600 t in 1999 and over 4080 t in 2000. In 2001, landings decreased to 1140 t (Table 7). The decline was associated with the closure of two of the three processing plants (Feindel 2002). The level of harvest nearly doubled in 2002 (2850 t) and again in 2003 (4470 t) with a smaller decrease in 2004 (4650 t). The total value of the fishery was USD 0.56 million in 2003 and USD 0.51 million in 2004.

Regulations were implemented in March 2000 under the 1999 Sustainable Development of Emerging Fisheries Act. The Act included restrictions that limit the fishing season (closures between 1 July and 31 September), define gear size, and establish a maximum number of endorsements, with licenses given only to individuals that had sold 100,000 kg during the previous year. Licensed fishermen are required to submit log-

books that include information on catch, time at sea, area fished, and catch value (Feindel 2002). The number of sea cucumber endorsements have ranged from 10–13 per year between 2001–2004. These new regulations were intended to address concerns of possible depletion of the resource as interest in the fishery peaked, and to address gear conflict issues between sea cucumber and lobster fisheries.

Domestic consumption and international trade

Traditional methods of preserving of sea cucumbers include drying, smoking, canning or freezing. Sea cucumbers are prepared for consumption by being gutted and then boiled or roasted. Sea cucumber processing plants are located in Maine, Massachusetts and Washington. The primary commercial products derived from sea cucumbers include the internal muscle bands and the dried body. Processing of sea cucumbers involves removing the end with the tentacles, slitting the body lengthwise to remove the viscera, and scraping the muscles off the body wall. The body and muscles are typically boiled, dried and salted before export, while lesser quantities are marketed as a frozen, pickled or live product. The byproduct of processing from *C. frondosa* is marketed in the United States as a nutritional supplement providing chondroitin (*NutriSea*), is also sold as a treatment for arthritis for people (*ArthriSea* and *SeaCuMAX*) and pets (*Sea Jerky*) (Coastside Bio Resources, Stonington, Maine), and is marketed as compost in Maine (Feindel 2002).

Most of the sea cucumbers harvested in the US Pacific are exported to Hong Kong, Chinese Taipei, mainland China and Korea. Exports of *Parastichopus* spp. were worth USD 0.07 kg⁻¹ in the early 1980s, which had increased to USD 0.82 kg⁻¹ in 2005; processed sea cucumbers can sell for up to USD 9 kg⁻¹ (wholesale). Total ex-vessel revenue for Washington and California fisheries has varied from USD 1,000,073 in 1999 to a maximum of USD 4,848,999 in 1993, with most revenue associated with the Washington State fishery in the early

Table 7. Summary of available information on commercial landings of sea cucumbers in the United States in metric tonnes (t), live weight. Data for Alaska, California and Washington are from Pacific Fisheries Information Network (2005).

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Alaska	693.5	786.7	670.0	485	465.8	543.4	764.6	578.0	721.7	821.0	807.4	830.01
Oregon	2.3	4.8	0.0	0.0	2.9	0.0	0.003	0.1	0.01	0	0.31	0.12
California	265.8	293.0	267.6	381.0	193.0	341.0	272.0	291.0	325.5	429.5	344.1	260.0
Washington	1281.3	684.4	529.1	290.0	248.2	239.3	228.0	275.0	300.1	249.1	199.0	262.2
Maine		1451.0	1950.0	1270.0	453.0	2359.0	3630.0	4080.0	1141.0	2845.0	4467.0	4650.0

1990s; the ex-vessel value fluctuates substantially due to annual variations in total harvest and high variability in the price received for each landed kg (Fig 1). In Maine, fishermen are paid USD 0.05–0.06 per unprocessed *C. frondosa*. Internal muscle bands and the dried body wall are the primary export products, and are currently worth about USD 1.59 kg⁻¹. After harvest the animals are either loaded onto refrigerated trucks at the dock and shipped to Seattle for processing, or they are processed in Maine and shipped directly to mainland China, Hong Kong, South Korea, Singapore, Chinese Taipei and Japan. Chinese markets in San Francisco, New York and other cities within the United States also purchase a portion of the sea cucumber catch.

The US west coast also serves as a transshipment point for sea cucumbers originating in Latin America en route to Asia. Los Angeles, California is the primary port of entry for the aquarium trade, with most sea cucumbers originating in Southeast Asia. The genus *Pseudocolochirus* is the dominant import, although several smaller species such as *Pentacta anceps* and *Colochirus robustus* are also available. One Caribbean species, *I. badionatus*, is commonly imported and also collected in US waters.

Conservation concerns

There have been some problems associated with sea cucumber fisheries, including the potential for overexploitation, habitat damage, bycatch, illegal fishing activities, and conflicts with other resource uses. In many locations sea cucumber landings increased rapidly following exploratory phases, but some fisheries have also experienced decreases in the number of sea cucumbers landed per dive, and overexploitation has been reported from some areas. Fishery sustainability is a major concern for US sea cucumber populations, particularly for stocks that lack stock assessments. Several states are implementing sea cucumber monitoring programs, and there has also been an increase in research efforts to better understand sea cucumber reproduction, growth, recruitment, distribution and abundance (Shroeter et al. 2001; Cameron and Frankboner 1989). For example, fishery-independent monitoring conducted in the Channel Islands and Santa Barbara Islands off California has revealed a decline in sea cucumber populations within fished areas since 1990, with populations that are 50–80% smaller than that observed in sites that were fished (Rogers-Bennet and Ono 2001).

Illegal fishing has been reported from California. This was primarily associated with 16 trawl fishermen that fraudulently obtained sea cucumber permits, and has been subsequently addressed.

During the development of the sea cucumber fishery in Southeast Alaska, concerns existed about potential conflicts between subsistence and commercial harvesters. These conflicts have been largely addressed through the implementation of a fishery management plan, which established conservative harvest rates in specific areas that for subsistence preference be closed to commercial harvest. Other long-term management options that have been proposed include identifying subsistence areas that should be closed to commercial harvesting (Mathews et al. 1990).

The primary concern associated with the Maine sea cucumber fishery is that most of the fishing effort is concentrated in a few sites in three locations in eastern Maine, and there are anecdotal reports that some sites have been fished out. Substantial amounts of bycatch are associated with the fishery in muddy and gravel environments, while bycatch is low in rocky areas where the species forms dense aggregations (Feindel 2002).

Impacts associated with the use of non-selective gear, such as trawls, include potential habitat damage and bycatch. These impacts are being minimized through 1) implementation of area closures for trawling in sensitive habitats (Washington, California and Alaska); 2) seasonal or spatial closure to protect other species (e.g. shrimp) during key life history stages such as reproductive periods (Washington and Alaska); and 3) restrictions on the size and type of bottom tending gear that can be used in the fishery (Maine).

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