

## 5. SEA CUCUMBERS

### Overview of the Fishery

Sea cucumbers have been harvested in parts of the western Pacific for hundreds of years, and more recently the fisheries have expanded worldwide, involving the harvest of nearly 50 species. Two species of sea cucumbers are fished in California: the California sea cucumber, *Parastichopus californicus*, also known as the giant red sea cucumber, and the warty sea cucumber, *P. parvimensis*. The warty sea cucumber is fished almost exclusively by divers, while the California sea cucumber is caught principally by trawling in southern California, but is also occasionally targeted by divers in northern California. There is an artisanal dive fishery for warty sea cucumbers in Baja California, Mexico, and commercial dive fisheries are conducted for California sea cucumbers in Washington, Oregon, Alaska, and the coast of British Columbia, Canada.

The first recorded commercial landings of sea cucumbers in California were made in 1978 at Los Angeles area ports (Figure 5.1 and Table 5.1). Divers fishing warty sea cucumbers at Santa Catalina Island were the first to make landings, but they were soon joined by trawl vessels. Combined annual landings remained under 100,000 pounds (45 metric tons) until 1982, when the principal fishing area shifted to the Santa Barbara Channel. In that year, 140,000 pounds (64 metric tons) were landed with an ex-vessel value of about \$25,000. Recorded landings fluctuated from 52,000 to 160,000 pounds (24 to 73 metric tons) over the next eight years, and in 1991 reached more than 577,000 pounds (262 metric tons). Through the first 18 years of the fishery, trawl landings composed an average of 75 percent of the annual sea cucumber harvest, but between 1997 and 2002, sea cucumbers landed by divers accounted for 70 to 88 percent of the combined dive and trawl landings. During that time period, trawl effort declined substantially, primarily due to court cases pursued by the Department of Fish and Game, which ruled that 16 trawl fishermen had fraudulently obtained their sea cucumber permits. Those fishermen were subsequently excluded from the fishery.

Diver effort and landings, in contrast, increased markedly from 1997 on, driven by a 1997 moratorium of the abalone fishery, a sea urchin fishery depressed by El Niño conditions, and a poor Japanese export market. Beginning in 1997, many commercial sea urchin or abalone divers, who also held sea cucumber permits, targeted sea cucumbers more heavily than before. In 2002, combined trawl and dive sea cucumber landings reached an all time high of 944,700 pounds (429 metric tons) with an ex-vessel value of \$797,748. In the four years since 2002, the trawl catch has remained relatively stable, while the dive fishery has declined, averaging 300,000 pounds (136 metric tons) of warty sea cucumber annually. Part of the drop in the diver catch can be attributed to a shift in diver effort from warty sea cucumber to red sea urchin harvesting, especially at the northern Channel Islands, where a substantial segment of the fishery for both species occurs. Fishing revenue from the 2006 commercial harvest of sea cucumber was about \$188,000 (ex-vessel 2006 dollars). The contribution to total business output, for the State, from this 2006 commercial harvest is estimated to be \$363,000. Likewise, total employment and wages from sea cucumber is estimated to be the equivalent of 7 jobs

and \$167,000, respectively.

Most of the California and warty sea cucumber product is shipped overseas to Hong Kong, Taiwan, mainland China, and South Korea. Asian markets within the United States also purchase a portion of California's sea cucumber catch. The majority are boiled, dried, and salted before export, while lesser quantities are marketed as a frozen, pickled, or live product. The processed sea cucumbers can sell wholesale for up to \$20 per pound. In Asia, sea cucumbers are claimed to have a variety of beneficial medicinal or health enhancing properties, including lowering high blood pressure, aiding proper digestive function, and curing impotency. Studies of the biomedical properties of various sea cucumber chemical extracts, such as saponins, and chondroitin sulfates, are being conducted by western medical researchers investigating the efficacy of these substances for pharmaceutical products used in the treatment of arthritis, and as nutritional supplements.



Sea cucumbers are placed on outdoor drying racks after having been, slit, eviscerated, and boiled.

Credit: Dave Ono

There is no significant sport fishery for sea cucumbers in California. Sea cucumbers fall under the general 35 count bag limit for the sport take of many invertebrate species. Additionally, sport fishing regulations prohibit the take of sea cucumbers within 1,000 feet (305 meters) of the high tide mark, and few sport divers have shown an interest in harvesting sea cucumbers as a food item.

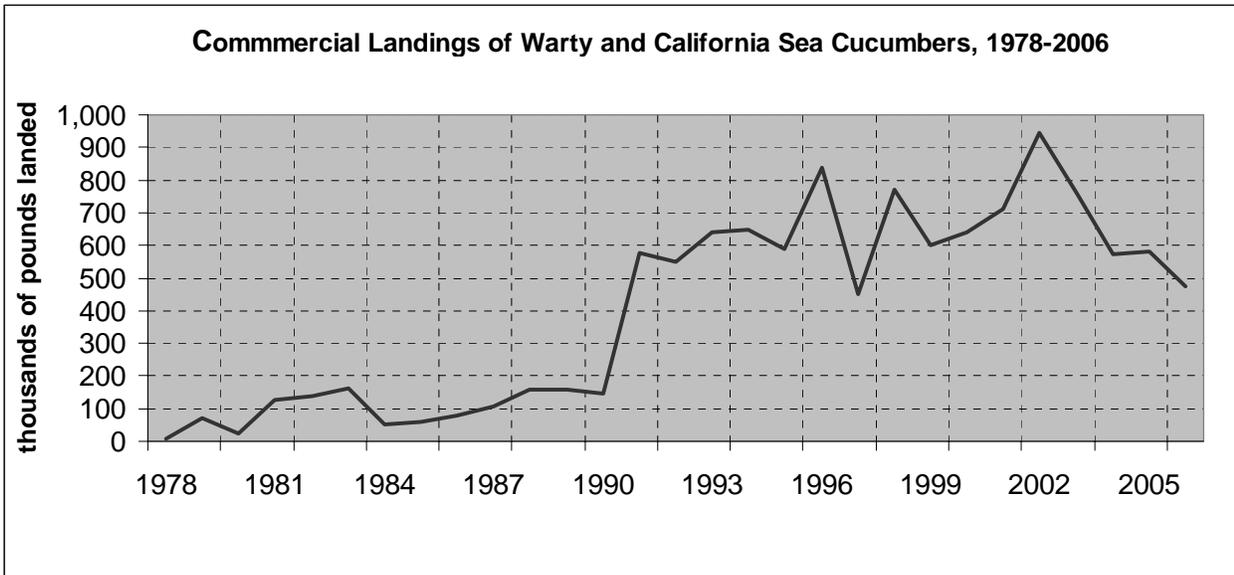


Figure 5.1 Annual combined commercial landings (pounds) of warty and California sea cucumbers from 1978 to 2006. Data from California Department of Fish and Game (DFG) Catch Bulletins (1978-1983) and the DFG commercial landing receipt database (1984-2006).

### Restricted Access Program

A special permit to fish for sea cucumbers commercially was required beginning with the 1992-1993 fishing season. Qualifications for the permit were based upon meeting a minimum 50-pound (22.7-kilogram) landing requirement during a four-year window period.

#### Historical timeline for the commercial sea cucumber fishery restricted access program

- 1992** *Section 8396*; Fish and Game Code. Required fishermen to obtain a sea cucumber permit, issued to fishermen based on a qualifying minimum 50 lb landing of sea cucumbers made between 01/01/1988 and 06/30/1991
- 1994** *Section 8396*, Fish and Game Code, amended. Allowed some trawl fishermen to obtain sea cucumber permits on appeal, without having to meet the minimum landing requirement. Specified that sea cucumber permits were non-transferable and established a \$250 annual permit fee.
- 1997** *Section 8407*, Fish and Game Code. Repealed section 8396 of the Fish and Game Code; instituted separate trawl and dive sea cucumber permits; set up a permit transfer mechanism, and set a ceiling of trawl and dive permittees allowed in the fishery, based on the number of permits issued during the 1997-98 license year.

In 1997, legislation was enacted that imposed a new regulatory regime on the sea cucumber fishery. The major regulatory changes included creating separate permits for each gear type, and limiting the total number of permittees in the sea cucumber fishery. A permit transfer procedure and transfer fee of \$200 was also initiated by the 1997 legislation. Sea cucumber dive permits must remain dive permits if transferred, while sea cucumber trawl permits if transferred may remain trawl permits or be converted to a dive permit.

The maximum number of permits allocated was based on the number of permits issued during the 1997-1998 permit year and the meeting of a minimum landing requirement. In 2000, there were 113 sea cucumber dive permittees and 36 trawl sea cucumber permittees. By 2006, a number of dive and trawl fishermen had left the fishery, and there were 92 sea cucumber dive permittees and 20 sea cucumber trawl permittees remaining.

### Status of Biological Knowledge

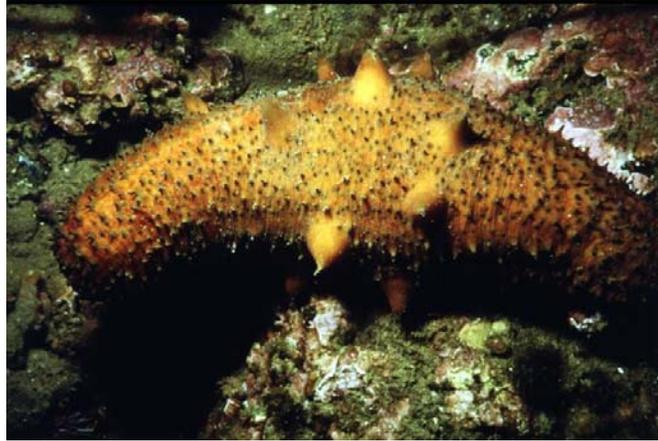
Sea cucumbers are long, soft-bodied, marine invertebrates in the class Holothuroidea. They are related to other organisms in the phylum Echinodermata such as sea urchins and sea stars. Their skeleton has been reduced to small calcareous pieces (ossicles) in the body wall, which have distinct species-specific shapes.

The California sea cucumber reaches a maximum length of 24-inches (61-



California sea cucumber, *Parastichopus californicus*  
Credit: Dave Ono

centimeters) and is red brown or yellow in color with red-tipped papillae. The warty sea cucumber is 12 to 16-inches in length (30.5 to 40.6-centimeters) and chestnut brown with black tipped papillae on the ventral surface. Comparatively few studies have been done with eastern Pacific sea cucumbers, and as recently as 1986, a new *Parastichopus* species, *P. leukothele*, was described that is distributed from Pt. Conception, California to British Columbia, Canada at depths of from 80 to 940 feet (24 to 287 meters). It resembles the California sea cucumber in size and shape but has white papillae or tubercles.



Warty sea cucumber, *Parastichopus parvimensis*  
Credit: DFG

Sea cucumbers are broadcast spawners with fertilization taking place in the water column. Sea cucumber size is difficult to determine, since they can contract dramatically, making length measurements unreliable. Furthermore, they can take up large quantities of seawater, rendering body weights unreliable.

The California sea cucumber is distributed from Baja California to Alaska. The warty sea cucumber is distributed from Baja California to Monterey Bay, although it is uncommon north of Pt. Conception. The California sea cucumber is found from the low intertidal to 300 feet (91 meters), and the warty sea cucumber is found from the low intertidal to 90 feet (27 meters), generally in areas with little water movement.

Sea cucumbers are epibenthic detritivores that feed on organic detritus and small organisms within sediments and muds. Buccal tentacles trap food particles using an adhesive mucus. Sea cucumbers are non-selective with respect to grain size and ingest only the top few millimeters of sediment. One study of warty sea cucumbers around Santa Catalina Island found that those living on rock rubble were 27 percent smaller and seven times more numerous than those residing on sandy substrates. The detritus on rock rubble was found to have three times more organic material per gram compared to the detritus from the sand substrate, and sea cucumbers on the sand ingested eight times more sediment. In a recent study, California sea cucumbers were found to have the highest densities on shell debris, gravel, and boulders, and the lowest on mud and silt bottoms.

Sea cucumbers can reach moderately high densities and are thought to be important agents of bioturbation. During feeding and reworking of surface sediments, sea cucumbers can alter the structure of soft-bottom benthic communities. The California sea cucumber can crawl an average of 12 feet (4 meters) per day, exhibiting no directional bias, presumably due to the even distribution of detrital food. Tagging studies are difficult since external tags are frequently lost and internal tags can be shed through the body wall.

Sea cucumbers are also known to have a predator escape response involving a rapid creeping or swimming behavior, which propels them away from danger. Water can also be taken up in the respiratory tree and then forcefully discharged to discourage attackers. Predators include sea stars, including the sunflower star, *Pycnopodia helianthoides*; various fishes such as kelp greenlings, *Hexagrammos decagrammus*; sea otters, *Enhydra*

*lutris*; and crabs. *P. californicus* is host to a worm-like internal parasitic gastropod, *Enteroxenos parastichopoli*, and an external parasitic snail, *Vitriolina columbiana*. Both sea cucumber species can also serve as a commensal host to the polychaete scale worm, *Arctonoe pulchra*.

Sea cucumbers have a distinctive spawning posture, detaching from the substrate and forming an S-shape to release their gametes up and away from the benthic boundary layer (Figure 5.2). There are separate sexes and the sex ratio is approximately one to one. Individuals do not form spawning aggregations. Spawning is partially synchronous with a portion of the population spawning simultaneously. Triggers for spawning are largely unknown, however spawning is thought to coincide with phytoplankton blooms during sunny days in late spring and summer. Oocytes are light orange in color and surrounded by a jelly coat. After fertilization, the embryo hatches into the gastrula (64 hours) and starts to swim. A feeding auricularia larva develops 13 days after fertilization and begins ingesting phytoplankton. The auricularia develops into a doliolaria larva (37 days post-fertilization) losing up to 90 percent of its body volume and rearranging its ciliary bands. The final doliolaria larval stage metamorphoses (51 to 91 days post-fertilization) into a newly settled pentactula. Pentactula have five primary buccal tentacles, and attach

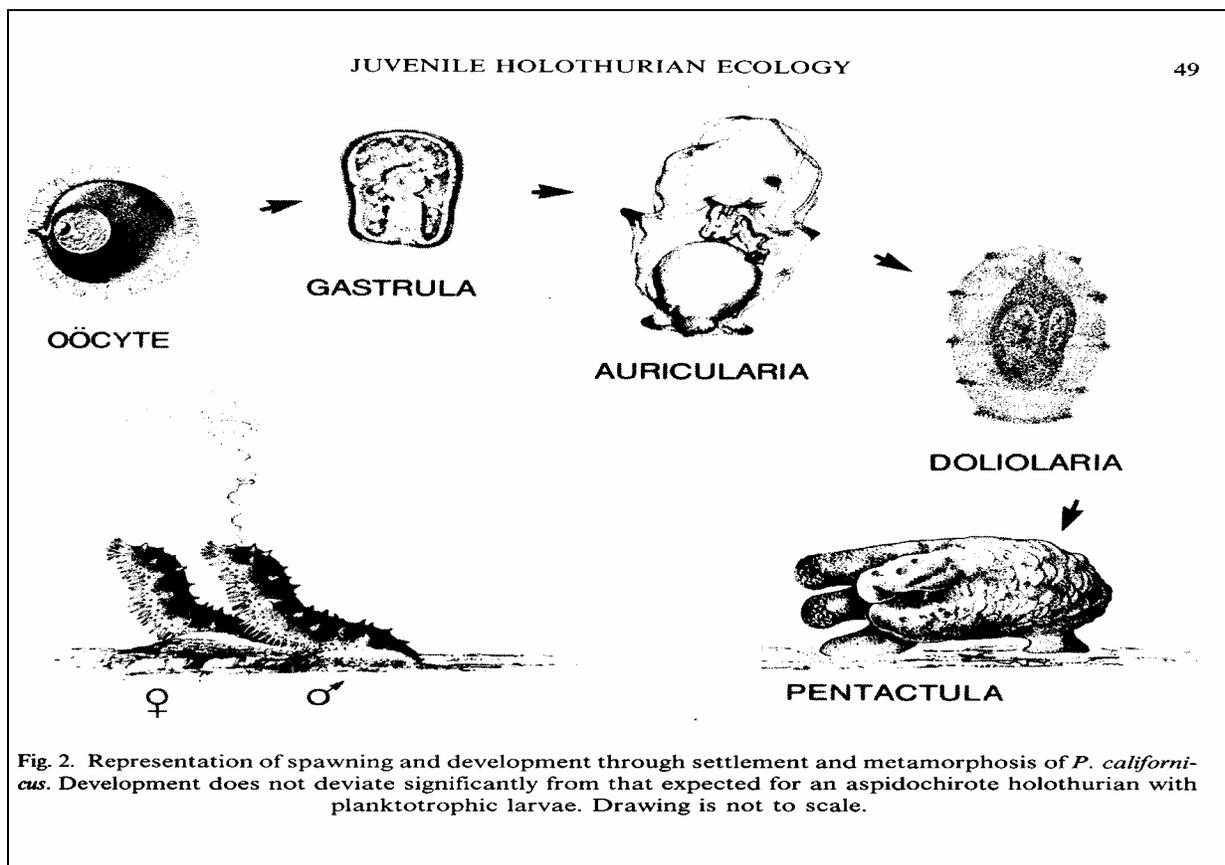


Figure 5.2. Life History of the California sea cucumber, *Parstichopus californicus*, (from Cameron and Frankboner. 1989. *Journal of Experimental Marine Biology and Ecology*, 127, 43-67)

to the substrate using a single pedicle. In the field, juveniles recruit to a variety of substrates, including rocky crevices, polychaete worm tubes, and filamentous red algae. Growth is slow in sea cucumbers. Juveniles become reproductively mature at 4 to 8 years.

Both species of sea cucumber undergo visceral atrophy each year. During atrophy the gonad, circulatory system, and respiratory tree are resorbed and reduced in size, and the gut degenerates. Feeding and locomotion stop prior to visceral atrophy, which occurs in the fall. Following the resorption of the visceral tissue the animal loses 25 percent of its body weight. The weight of the body wall cycles during the year, being the lowest early in the year and the highest in early fall prior to the start of visceral atrophy. Within two to four weeks regeneration begins, starting with the gut tube, then the respiratory tree and circulatory system, and finally the gonad regrows branched tubules. Juveniles also undergo yearly visceral atrophy; however, they do not have gonads at this stage. In the fall, animals may spontaneously eviscerate internal tissues if handled roughly, although this is not a common occurrence.

### **Status of the Populations**

There is presently very little known about the population size of either California or warty sea cucumbers in California. The distribution of these species on rocky or sandy substrates is characterized as patchy, but warty sea cucumbers have demonstrated a seasonal aggregating behavior, possible as a precursor to spawning. Both sea cucumber species are also known to make seasonal vertical depth migrations. Sea cucumbers undergo sporadic recruitment, have a relatively high natural mortality, and are slow growing. Species with these life history traits tend to have a low maximum yield per recruit and are particularly vulnerable to overfishing.

The Channel Islands National Parks Service has been monitoring warty sea cucumbers at 16 sites in the northern Channel Islands and Santa Barbara Island since 1982 (Figure 5.3). These fishery independent data show that populations of warty sea cucumber are variable but have been declining at fished sites since 1990. Meanwhile, sea cucumber catches from the dive fishery have increased at some of these sites. Recent analysis comparing population trends at fished sites to those of two small reserves where fishing is prohibited indicate that populations at fished sites range from 50 to more than 80 percent lower than at protected sites.

Fishery independent sea cucumber density estimates have also been made using underwater video technology. Preliminary observations of California sea cucumbers in an established reserve in northern California (Point Cabrillo Marine Protected Area) at depths of 150 to 180 feet (46 to 55 meters) revealed densities averaging around 1,000 per acre (405 per hectare). By comparison, densities at a newly established reserve (Punta Gorda Ecological Reserve) were much lower, ranging from 120 to 350 per acre (49 to 142 per hectare). Only the large size classes were observed in these surveys, suggesting low levels of recruitment.

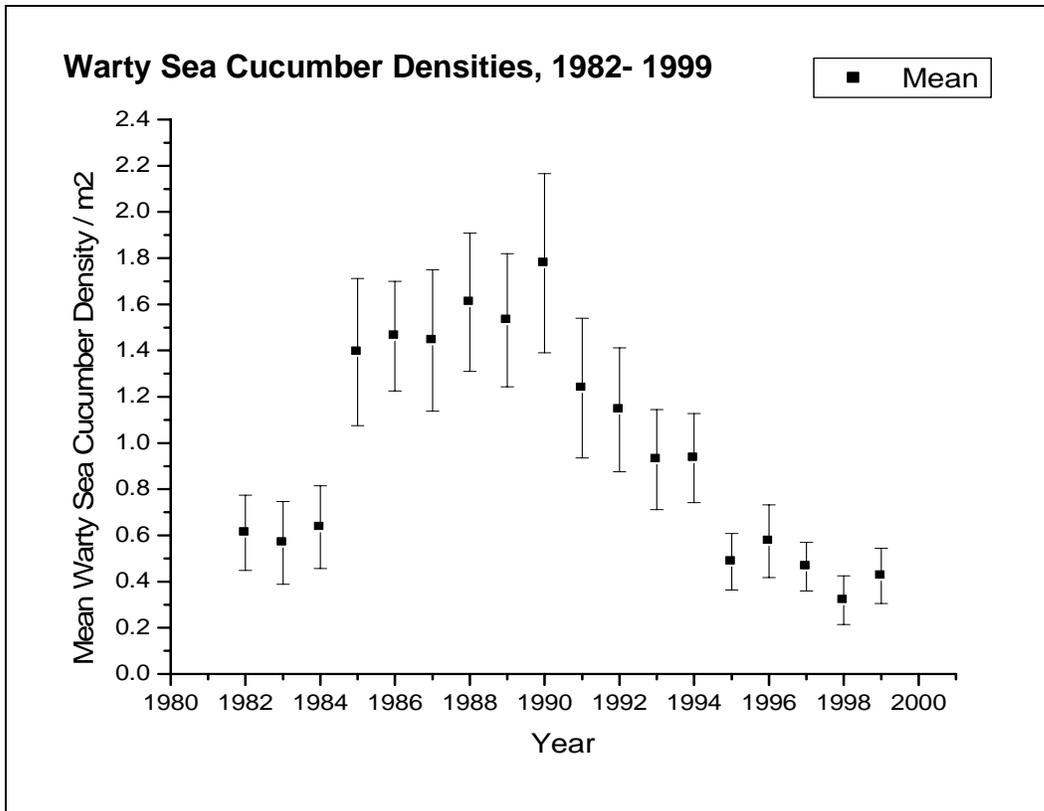


Figure 5.3 Density of the warty sea cucumber, *P. parvimensis*, quantified by the Channel Islands National Park at the northern Channel Islands (1982-1999).

### Management Considerations

It is unknown if the current levels of fishing effort and harvest are sustainable, and whether the stocks of warty and California sea cucumbers are robust enough to support those fisheries over the long term. There are several activities that could help indicate the effectiveness of current management regulations:

- Maintain the logbook reporting requirements for the dive and trawl sea cucumber fisheries. In order to manage these two fisheries, it is important to know the quantities, location, and depths of each species taken. In 2003, individual codes were assigned to each sea cucumber species in the DFG landing receipt database.

- Additional fishery independent information could help inform management decisions for this fishery. Submersible, ROV, or diver video surveys of fished and unfished areas are potentially useful activities.
- Efforts to collect field data necessary to perform stock assessments and generate biomass estimates for both the warty and California sea cucumber would lay the foundation for improved management of these resources. The biological, catch, effort, and catch-per-unit-of-effort (CPUE) parameters derived from logbook data, along with field observations of sea cucumber distributions and densities, could be used to model the impact of different levels of fishing intensities. However, due to difficulties in interpreting CPUE data for dive fisheries, it would be preferable to conduct population modeling using fishery-independent data sources for abundance trends, such as described above.
- Finally, if the limited entry restrictions on the dive and trawl sea cucumber fisheries do not adequately limit the take of sea cucumbers at sustainable levels, additional management options, such as individual or area quotas, or seasonal closures, may be required. The restricted access regulations imposed on the dive and trawl sea cucumber fisheries in 1997 have effectively capped the number of sea cucumber permittees, and, have, over the proceeding nine years, contributed to a reduction in the number of licensed harvesters engaged in both fisheries. What has yet to be determined is whether the resultant levels of fishing effort and harvest are sustainable, and whether the stocks of warty and California sea cucumbers are robust enough to support those fisheries over the long term.

**Laura Rogers-Bennett**

Senior Marine Biologist, Bodega Bay, ([Lrogersbennett@dfg.ca.gov](mailto:Lrogersbennett@dfg.ca.gov))

**David S. Ono**

Marine Biologist, Santa Barbara, ([Dono@dfg.ca.gov](mailto:Dono@dfg.ca.gov))

Revised May 2007

**David S. Ono**

Marine Biologist, Santa Barbara, ([Dono@dfg.ca.gov](mailto:Dono@dfg.ca.gov))

**Further Reading**

Anonymous. 1983. Guide to the underutilized species of California. Natl. Mar. Fish. Serv. Admin. Rept. No. T-83-01. 24 p.

Bruckner, Andrew W. 2005. The recent status of sea cucumber fisheries in the continental United States of America. Beche-de-mer information Bulletin, 22:39-46.

Cameron, J.L. and Fankboner, P.V. 1986. Reproductive biology of the commercial sea cucumber *Parastichopus californicus* (Stimpson) (Echinodermata: Holothuroidea). 2.

Observations on the ecology of development, recruitment, and the juvenile life stage. *J. Exp. Mar. Biol. Ecol.* 127:43-67.

DeMorgan, P. and J. B. Richards. 2001. California sea cucumber diagnostic report: a collaborative review of the fishery. California Seafood Council and RESOLVE Inc. 63 p.

Lambert, P. 1997. Sea cucumbers of British Columbia, southeast Alaska and Puget Sound. University of British Columbia Press. 166 p.

Mottet, M.G. 1976. The fishery biology and market preparation of sea cucumbers. Wash. Dept. Fish. Shellfish Program, Tech. Rep. 22. 57 p.

Muse, B. 1998. Management of the British Columbia sea cucumber fishery. Alaska Commercial Fisheries Entry Commission, Alaska. 19 p.

Phillips, A.C. and J.A. Boutillier. 1998. Stock assessment and quota options for the sea cucumber fishery. *In* Invertebrate Working Papers reviewed by the Pacific Stock Assessment Review Comm. Edited by Waddell, B.J., G.E. Gillespie, and L.C. Walthers. (PSARC) Can. Tech. Rep. Fish. Aquat. Sci./ Rapp. Tech. Can. Sci. 2215: 147-165.

Schroeter, S., D. Reed, D. Kushner, J. Estes, and D. Ono. 2001. The use of marine reserves for fishery independent monitoring: a case study for the warty sea cucumber, *Parastichopus parvimensis*, in California, U.S.A. *Canadian Journal of Fisheries and Aquatic Sciences* 58:1773-1781.

Woodby, D., S. Smiley, and R. Larson. 2000. Depth and habitat distribution of *Parastichopus californicus* near Sitka, Alaska. *Alaska Fishery Research Bulletin* 7:22-32.

Zhou, S. and T. Shirley. 1996. Habitat and depth distribution of the red sea cucumber *Parastichopus californicus* in Southeast Alaska Bay. *Alaska Fishery Research Bulletin* vol. 3, 2:123-131.

<b>Table 5.1 Commercial Landings (Pounds) of Sea Cucumbers, 1978-2006</b>					
<b>Year</b>	<b>Pounds</b>	<b>Year</b>	<b>Pounds</b>	<b>Year</b>	<b>Pounds</b>
<b>1978</b>	8,780	<b>1988</b>	159,106	<b>1998</b>	770,679
<b>1979</b>	69,438	<b>1989</b>	160,011	<b>1999</b>	600,875
<b>1980</b>	23,060	<b>1990</b>	147,284	<b>2000</b>	638,376
<b>1981</b>	128,362	<b>1991</b>	581,974	<b>2001</b>	712,660
<b>1982</b>	139,487	<b>1992</b>	549,191	<b>2002</b>	944,702
<b>1983</b>	163,495	<b>1993</b>	646,210	<b>2003</b>	758,567
<b>1984</b>	52,354	<b>1994</b>	646,926	<b>2004</b>	572,397
<b>1985</b>	59,076	<b>1995</b>	598,888	<b>2005</b>	580,020
<b>1986</b>	77,697	<b>1996</b>	839,382	<b>2006</b>	476,108
<b>1987</b>	107,678	<b>1997</b>	452,640		

Data sources: CDFG Catch Bulletins (1916-1983) and CDFG commercial landing receipts (1984-2006).