

**BIODIVERSITY OF MARINE
COMMUNITIES IN PEARL HARBOR,
OAHU, HAWAII WITH OBSERVATIONS ON
INTRODUCED EXOTIC SPECIES**

Final Report prepared for the U. S. Navy

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EXECUTIVE SUMMARY

Although Pearl Harbor was heavily utilized by Hawaiians for fishing, food gathering and fish cultivation in dozens of fishponds prior to twentieth century, it was relatively isolated from the open ocean before completion of the Pearl Harbor entrance channel in 1911. This marked the beginning of access to the harbor of ocean going vessels with a draft of greater than 5 m and greatly increased the opportunity for species introductions. Other dramatic environmental changes such as the increased runoff of sediment-laden water from the Pearl Harbor watershed that began in the middle of the nineteenth century, filling of fishponds and conversion of shorelines to accommodate docking of U. S. Navy ships and disposal of wastes into the harbor greatly altered the conditions in which organisms lived. The habitat of Pearl Harbor has therefore been an environment of shifting characteristics since at least the beginning of European contact at the end of the eighteenth century.

This study collected or observed a total of 434 species or higher taxa (36 algae, 1 spermatophyte, 338 invertebrate and 59 fish) from the 15 stations sampled, the highest number of taxa that have been collected for any Pearl Harbor study. Ninety six species, or about 22%, are considered to be introduced or cryptogenic. The areas of highest species richness were in the entrance channel and in Rainbow Bay at the northeast head of East Loch where number of taxa were around 150. Lowest species richness occurred in the areas of high sedimentation and turbidity at the head of West Loch where fewer than 50 taxa occurred. Dendrographs based on Sorensen Indices of Similarity of species composition among stations suggest three types of communities in the harbor, one associated with relatively oceanic conditions in channel areas, one with the highly turbid West Loch sedimentary environment and one with conditions prevailing throughout the rest of the harbor.

Historically, a total of 1141 taxa have been reported by all sources (including the present study) for the harbor, with 1061 of these reports dated. One hundred sixty six of the total 434 taxa found in the present study are new species reports for Pearl Harbor, and 33 of these are new reports for Hawaii. Analysis of the data for numbers of taxa reported for Pearl Harbor by decade suggests three periods when there were large increases in the numbers of species reported: in the 1920s to 1930s, the 1970s and the 1990s. All of these correspond to periods of increased sampling activity in the harbor and are therefore primarily effort related.

The 96 species collected in the present study that are considered to be introduced or cryptogenic include 55 previously reported in Hawaii and considered introduced, 19 previously reported and considered cryptogenic, 14 new reports for Hawaii considered cryptogenic and eight new reports considered introduced. The eight new introductions were comprised of four bivalve molluscs, one pycnogonid, one barnacle, one grapsid crab and one ascidian. Except for the barnacle, none of these recently introduced species have attained large population sizes or wide distributions, and none appear to represent a serious competition to other species already established in Pearl Harbor or elsewhere in

Hawaii. By contrast, the barnacle *Chthamalus proteus*, which is widespread in the Pearl Harbor intertidal and appears to have been introduced to Hawaii since the early 1970's, is now the most abundant intertidal organism in many areas in the harbor and abounds in other Hawaiian embayments on Oahu, Maui, Hawaii and Kauai.

A total on 99 species that are considered to be nonindigenous and introduced have been collected from Pearl Harbor since sampling began at the beginning of this century. The 63 introduced species that occurred in the harbor in 1996 represent an average of 64% of total introductions, indicating a high level of persistence of introduced species after their introduction. Persistence rates by decade ranged from as high as 100% for the six species that were first collected in the harbor in 1911-1920, to 30% for the six introduced species first reported in the 1960s.

Most of the introduced species (42%) occur in tropical or temperate oceans worldwide, prohibiting conclusions about their origin of introduction. For the remainder, the majority (27%) have previously known distributions or origins extending to the western Indo-Pacific and Red Sea, and the general Indo-Pacific region (12%). Introduced species from the eastern Pacific region accounted for only 3% of the total introductions, and species with Atlantic and Mediterranean distributions were only 15%, with over half of these coming from the western Atlantic region.

Comparison of the present study's results with comprehensive surveys that were conducted in Pearl Harbor in the early 1970s suggests that the environmental conditions in the harbor are higher in quality and can support more stenotopic marine organisms than was the case 20 years ago. Naval shipboard effluent release in the harbor ceased in 1975, sewage discharges were removed in the 1980s except at the Fort Kamehameha outfall in the ship channel, and non-point source runoff has probably decreased in East and Middle Lochs due to completion of development and better land management practices. Probably as a result, reef corals are beginning to colonize hard substrata in the harbor along the ship entrance channel, West Loch and Middle Loch channels, near the entrance to Southeast Loch, and even on the Hawaiian Electric Co.'s discharge sheet piling and along the shoreline at Rainbow Bay in East Loch. No corals were found in the extensive studies conducted in the 1970s, and this change may suggest a reversion to conditions that probably have not existed in the harbor since pre-European contact.

In contrast to conditions that have been reported in many areas where recent introductions of nonindigenous aquatic species have eliminated native residents through rapid growth rates, competition for food resources and/or predation, we found little or no indication of monopolization of resources by a single species or population outbreaks of a recently introduced species. With the exception of the intertidal barnacle *Chthamalus proteus*, recently introduced species were few in number or single reports. Most previously reported introduced or cryptogenic species showed high abundances primarily in areas receiving specific environmental stress or enriched energy sources that favored the development of low diversity communities. Further studies should be conducted to determine whether other harbors and embayments in Hawaii have shown a similar levels of invasion by nonindigenous species or indications of recent introductions.