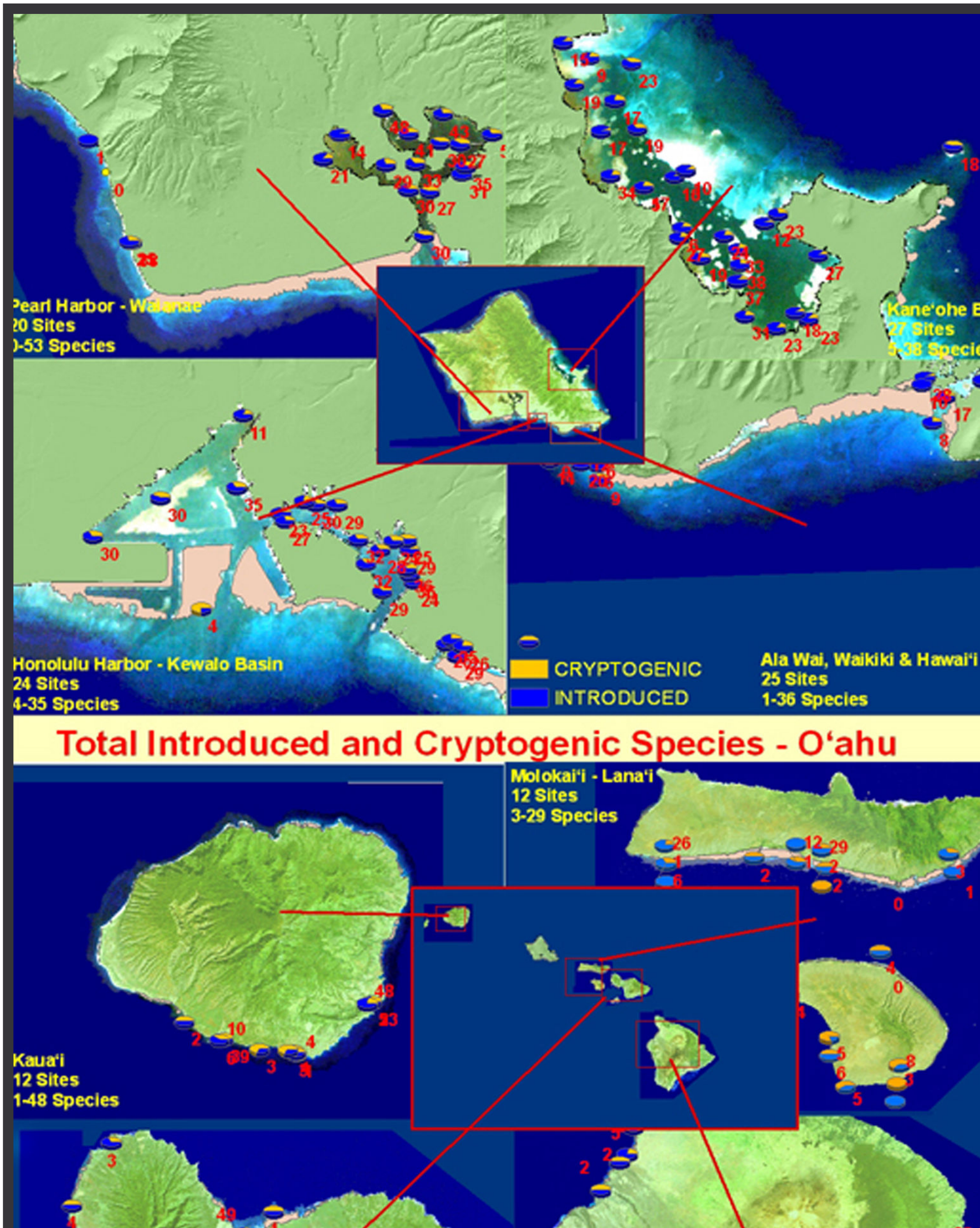

A Geographic Information System (GIS) Presentation of Introduced Marine Species Information for the Main Hawaiian Islands

Hawaii Biological Survey

Final Report March 2006

COVER

Maps of Total Introduced and Cryptogenic Species at Survey Sites
in the Main Hawaiian Islands

A Geographic Information System (GIS) Presentation of Introduced Marine Species Information for the Main Hawaiian Islands

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EXECUTIVE SUMMARY

All reports of introduced and cryptogenic species that have been determined by Bishop Museum researcher in projects conducted over the last ten years have been compiled into two Geographic Information System databases. These datasets and their associated maps enable the rapid comparison of the times and locations of 2741 reports of 212 species from 157 survey sites. These data are available in two mapping systems: 1) GIS analysis using ArcGIS 9.0©, which enables queries of the full data sets to focus on individual species, groups of species and relationships with environmental variables; 2) An innovative display designed to make information on the World Wide Web using the Google Earth platform. The capabilities of both approaches are described and examples provide which show some of the analyses that can be performed on the datasets.

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Introduction

Researchers from the Bishop Museum have conducted sampling and rapid assessments for nonindigenous (introduced) marine species at various locations throughout the Main and Northwestern Hawaiian Islands, Johnston Island and American Samoa. Within the Main Hawaiian Islands this activity has involved eight separately funded projects with observations and sampling at over 160 sites in the harbors and the coral reefs in of Kaua‘i, O‘ahu, Moloka‘i, Maui, Lāna‘i, Kaho‘olawe and Hawai‘i. Sites investigated include Pearl Harbor (Coles et al. 1997, 1999a), five commercial and small boat harbors on O‘ahu (Coles et al 1999b), eight harbors on the neighboring main Hawaiian Islands (Coles et al. 2004b), coral reef areas in Kāne‘ohe Bay (Coles et al. 2002a, 2004a), Waikīkī (Coles et al. 2002b), and harbors and coral reef areas at Kaua‘i, Moloka‘i, Lāna‘i, Maui, Kaho‘olawe, and Hawai‘i (Coles et al. 1998, 2004b, 2006). These surveys have found as many as 116 introduced species, comprising up to 23% of the total identified taxa, to occur within an given study area, i.e. Pearl Harbor. All of these studies have been conducted under the supervision of the same principal investigator with designations of introduced species status according to the Hawai‘i Checklist for Hawaiian Nonindigenous Species (Carlton and Eldredge unpubl.). This has provided the basis for a consistent estimate for the presence and composition of introduced species in a variety of marine habitats throughout the Hawaiian Islands.

The information from these studies, which have been conducted over a ten-year period, has been available in eight separate reports published by Bishop Museum and on its web site at http://hbs.bishopmuseum.org/hbspubs.html. Both the written reports and their electronic .pdf files contain extensive appendices that list all native, introduced and cryptogenic (i.e. neither demonstrably native or introduced) species at each observed or collected at site. Many of these surveys found over 650 total taxa, with over 100 introduced or cryptogenic species, and relating the findings of one study to another can be a daunting and time consuming task. There has been a need to organize and assemble all of the introduced species data for these studies into a single cohesive treatment for all of the areas surveyed and all the information available.

A convenient way to assemble and analyze large amounts of environmentally based data is to utilize a map-based Geographic Information System (GIS). By connecting introduced and cryptogenic species lists, location data, and environmental variables for the Bishop Museum report into a single GIS based data set, we have produced a spatial representation of the distribution of Hawai‘i’s marine alien species that will enable location, description and analysis of introduced marine species distributions throughout the Main Hawaiian Islands either by species or by higher taxonomic categories. Furthermore, the environmentally related data that has been included in the data set can be utilized to determine patterns for introduced/cryptogenic species or species groups in association with factors that may influence their distribution, such as proximity to harbors or exposure to or isolation from open ocean conditions.

Source Data and Methodology

The data set for this presentation and analyses was assembled from seven separate studies conducted from 1996 to 2005: Pearl Harbor (Coles et al. 1997, 1999a), O‘ahu South and West Shore Harbors (Coles 1999b), Kāne‘ohe Bay (Coles et. al. 2002a), Waikīkī and Hawai‘i Kai (Maunalua Bay) (Coles et al. 2002b), Neighbor Islands Coral Reefs (Coles et al. 2004a; in press), Neighbor Islands Harbors (Coles et al. 2004b) and Lanaʻi (Coles et al 2005). An additional study conducted at Kaloʻolawe (Coles et al. 1998), which found no introduced algae or invertebrates but did report introduced fish at unspecified sites, was not included in this analysis.

Station locations were recorded on site using Garmin 12 or Garmin 76 Global Positioning System (GPS) receivers at all sites except for the Pearl Harbor study, where station locations were estimated post hoc from landmarks readily recognizable on a map. Introduced and cryptogenic species reports were assembled from spreadsheets that had been used in the preparation of the above reports. Environmental data for the sites were prepared from observations and measurements were either made on site (Coles at al. 2004a, 2004b, 2006) or post hoc from the first hand knowledge of the site by the senior investigator. This location, species and environmental data were saved as three separate dbf files and then combined into an Access mdb master file linked through their station identities. This data set was then converted to an ArcGIS 9.0© layer using Arc Catalog© by designating the x and y coordinates in a UTM Zone 4N and NAD83 datum. Additional NAD83 layers were obtained from the State of Hawaiʻi GIS website (http://www.hawaii.gov/dbedt/gis/download.htm) for Hawaiʻi coastlines, coral reef locations, island topography and Landsat images for each island. An additional file of those images that were either from the senior investigator, Bishop Museum, or, with attribution, from various web sites was assembled and linked to the reported introduced or cryptogenic species.

Use Of ArcGIS©

ArcGIS 9.0© was used for the presentation and analysis of this study. This is a menu driven program that uses data from a single table or multiple linked tables that are related to a geographic coordinate system usually expressed in Universal Transverse Mercator (UTM) or Latitude-Longitude in decimal degrees. All data must be projected in a consistent datum, usually NAD83 or WGS84, which can be downloaded directly from coordinates recorded on site on a GPS receiver, or introduced as data from as text or dbf tables or Access .mdb files. The details of ArcGIS analysis are complex and too detailed to cover here, but an excellent interactive tutorial, CD with a six month limited license, and example problems (Ormsby et al. 2004) is available from the Environmental Science Research Institute (ESRI) at http://gis.esri.com/esripress/display/ndex.cfm?fuseaction=display&websiteID=49.

ArcGIS has a myriad of potential uses for determining patterns and relationships among geo-referenced environmental data. The GIS information is displayed as maps that each consist of a number of layers for the geographic area under consideration. Many layers are available without cost on web sites from various government or private agencies that can be used to show coastlines, rivers, roads, topography, satellite imagery, or other features that are useful for presentation or provide geographic realism to the map. However, the usefulness of the map is determined by the layer that the user creates from data for the presentation. The information contained in this layer can be viewed by opening an attribute table that contains all the attributes for the data set at column headings and their values in rows. For the present study, locations and patterns of distribution are shown for all the introduced and cryptogenic species that have been detected by Bishop Museum surveys over the past ten years at the various sites where surveys have been conducted. This information is presented in two data sets: one of which includes every species report by station and all associated environmental variables, the other including the total numbers of introduced and cryptogenic species and their sums.

The usefulness of a GIS presentation and analysis is greatly increased by using queries to reduce the data to manageable units corresponding to questions that the user might want to ask. Example are "where did invasive algae occur among all the stations that were surveyed" or "where did more than ten introduced species occur at more than 1 km from a harbor or pier?" The resulting reduced file can then be exported, stored and renamed as a new layer that shows the desired information. Using single or multiple sequential queries, a variety of patterns and relationships can be determined from that original data set that are only limited by the number of attributes that are in the master data set and the ingenuity and patience of the GIS user. This approach has been utilized in determining the following patterns.

Results

1. GIS Base Layer (Map File DAR AllData.mxd)

All the information for the study is contained in a single flat file named CombinedAlldata.shp, and the locations of the sites for these reports are shown in Figure 1 (many sites are overlapped and invisible in the map showing all of the Main Hawaiian Islands, but can be seen by zooming into a location on the map). As indicated, the data set comprises 2741 reports of 212 species at 157 sites throughout the Main Hawaiian Islands. Each yellow dot represents a single sampling site that had up to 53 introduced or cryptogenic species present. Details for the data that create the map are shown on the associated attribute table (Figure 2) which shows the species and higher taxa information for each site as well as its coordinates, totals numbers of introduced or cryptogenic species, project name, location, and survey date. In addition to the attribute columns shown in Figure 2, scrolling to the right on the table will show additional information for site regarding its distance from harbors, boat ramps and streams, and degree of isolation form the open ocean that can be used to evaluate numbers of introduced species in terms of probable environmental influences (Coles et al 2004a, in press).

Figures 3 and 4 show other basic information that can be directly derived from the base layer. By clicking on the Identify tool (4th form the right on tool bar) and then clicking on a given site the same information that exits as a line entry for a single species appears in a popup window. The example shown is for Station 1 at Iroquois Point in Pearl Harbor, from the first Bishop Museum species survey conducted in 1996, and shows that 30 introduced or cryptogenic species occurred at that site. Clicking on the Hyperlink tool at the right of the taskbar will produce a list of all introduced species at that site, and clicking on a name will show an image of that species if one is avaialable. (This requires that the hyperlink tool has been activated in the properties drop down menu for the layer).

2. Most frequently occurring species (Map File Most Frequent.mxd)

The most frequently occurring species can be determined by sorting on the species name column in the attribute table, which showed that these were the gastropod *Crepidula aculeata*, the polychaetes *Sabellastarte spectabilis* and *Branchiomma nigromaculata*, and the ascidian *Herdmania pallida*. To show the locations of these species alone, it is necessary to do perform a query to reduce the full data set down to the subject of interest. This is probably the most basic and generally useful process for the effective use of GIS. It is done by clicking on the Selection tab at the top left of the menu bar and then using the drop down menu that appears to make the desired query, in these cases selecting for species name. The resulting reduced file can then be saved as a separate map layer and displayed alone or with the original map layer. This has been done for the four maps in Figure 5, which show the full array of sites as yellow dots, with those containing colored dots indicating the sites where the respective species occurred. As indicated, the four most frequent species occurred at 64 to 75 of the 157 sites. Many f these sites are obscured by overlap at the scale of these maps, but in active use of GIS zooming in on the maps or displaying the attribute tables shows that most of these reports were in harbors or Kāneʻohe Bay.

3. Invasive Species (Map Files Invasive Algae, Invasive Invertebrates, Invasive Fishes)

The greatest concern about introduced marine species centers on those that are considered invasive, i.e. proliferate to the point that they consume or out-compete native species, alter the character of their adopted environment, or otherwise cause negative ecological or economic impacts. Eighteen species that occurred on these surveys are considered invasive in Hawaiʻi, seven macroalgae, one flowering plant, five invertebrates and five fishes. The distribution for five of the most invasive algae, four of the invertebrates and three of the fish were derived from querying the full data set and are shown in Figures 6-8. Invasive algae (Figure 6) occurred at 3 to 35 sites, *with Acanthophora spicifera* the most widespread and *Avrainvillea amadelpha* the least, occurring only at sites in Maunalua Bay, Oahu. Although *Eucheuma* sp. and *Kappaphycus* sp. occurred at 18 sites, all of these were in Kāneʻohe Bay, while *Gracilaria salicornia* occurred at 21 sites on Oʻahu and *Hypnea musciformis* was at 16 sites on Oʻahu and Maui. It should be noted that many sites were in harbors or on reefs in water deeper that the normal occurrence of these invasive algae. A more comprehensive distribution is provided in Smith et al. (2002)

The four invasive invertebrates were widely distributed, with the stomatopod *Gonodactylaceus falcatus* the most frequently reported, occurring at 56 sites at all of the islands except Hawaiʻi. However, the other three species, *Mycale armata, Carijoa riisei,* and *Cthamalus proteus*, were more widespread, occurring at 29 to 36 sites on all the islands, usually in harbor locations. Invasive fishes as a whole occurred at 72 sites, with the two most frequent, *Cephalopholis argus* and *Lutjanus kasmira* reported at open ocean sites, and tilapia (*Oreochromis mossambicus*) at 16 sites in Oʻahu harbors.

4. Total Introduced and Cryptogenic Species (Map Files Oʻahu Totals, Neighbor Island Totals)

The GIS base layer CombinedAll.shp that contains all of the species reports cannot be used to summarize totals for introduced or cryptogenic species at each site even those these data are provided in each entry. Almost all sites contained more than one species, which would result in redundant reports for totals. For this purpose another file named Total Crpt_Intro_Total.shp was created that included only site coordinates and total introduced and cryptogenic species at each site. These data are plotted as pie charts at each site showing the numbers of introduced species in blue and cryptogenic in brown, with their sum shown as a red number adjacent to each pie chart. Enlarged maps of the Pearl Harbor-Waianae, Kāneʻohe Bay, Honolulu Harbor-Kewalo

Basin, and Ala Wai harbor-Waīkiki and Hawaiʻi Kai areas are shown in Figure 9. Maps for Kauaʻi, Molokaʻi-Lānaʻi, Maui and Hawaiʻi Islands are shown in Figure 10. The maps indicate that the highest number of species encountered at any single site occurred in Pearl Harbor. Further enlargement of the map would show that this was 53 species recorded was at Rainbow Bay, first surveyed in February, 1996 and the first of all the 157 sites that were surveyed on all the studies. Other areas on Oʻahu and neighbor islands generally showed maximum ranges of around of up to around 40 species, with these maxima occurring in harbors, marinas or Kāneʻohe Bay. Maximum values outside of harbors were also influenced by whether number of species recorded were determined from on-site rapid assessments or collections and laboratory identifications. For reef rapid assessments, the maximum number of introduced and cryptogenic species was six, while collections showed up to 21 for the ten Neighbor Island reef sites where both rapid assessments and collections were made (Coles et. al. in press).

5. Sites with More Than 25 Introduced or Cryptogenic Species (Maps Oʻahu GT 25 Species.mxd, Neighbor Islands GT 25 Species.mxd).

To determine sites that had more than 25 introduced or cryptogenic species, the Total Crpt_Intro_Total.shp file was queried using the selection process preciously described and the resulting selected dated save as a shape file Total25.shp. The resulting maps (Figure 11 and 12) show that these locations were in harbors or marinas on all of the islands except Lānaʻi and in certain sections of Kāneʻohe Bay.

6. Sites Isolated from Open Ocean Circulation (Map Files Oʻahu High Isolation.mxd, Neighbor Islands High Isolation.mxd).

Isolation from open ocean circulation was determined from reef assemants to be the major factor related to higher numbers of introduced and cryptogenic species on reefs on the Main Hawaiian Islands (Coles et al. 2004a, in press). To determine which species totals corresponding to semi-enclosed (4) or highly enclosed (5) categories the two data sets CombinedAlldata.shp and Crpt_Intro_Total.shp were joined using a relate function in GIS that attaches the enivonmental variables in the CombinedAlldata.shp file to the single station listings in the Crpt_Intro_Total.shp file. The resulting file was queried for Isolation values greater than 3. The resulting reduced data sets mapped in Figures 13 and 14 show very similar patterns as those of Figures 11 and 12, with reports occurring in harbors, marinas or Kāneʻohe Bay ans high totals overall.

7. Sites Exposed to Open Ocean Circulation (Map Files Oʻahu Low Isolation.mxd, Neighbor Islands Low Isolation.mxd).

Using a similar process as above, the numbers of species corresponding to Isolation values of 1 (open ocean) or 2 (semi-exposed coastline) were mapped (Figures 15 and 16). Total introduced and cryptogenic species for these sites ranged 0 to 23, with the maximal values occuring on Oʻahu just inside or outside of Kāneʻohe Bay and off Waikīkī and Maunalua Bay. These totals were generally substantiality less than occurred at harbors sites in the same areas.

8. Sites Greater than 1 km from Harbors of Piers with Habors (Map Files Oʻahu Piers GT 1km.mxd, Neighbor Island Piers GT 1km.mxd)

The combined CombinedAlldata.shp Crpt_Intro_Total.shp file was queried to show those sites which were more than 1 km from harbors or from piers within harbors to determine whether introduced and cryptogenic species decreased with distance from a likely source of introduction. The resulting patterns (Figure 17 and 18) indicate that this is not the case for sites within harbors or emabayments on Oahu, where up to 43 species occurred at this distance in East and West Lochs in Pearl Harbor and 34 species in Kāneʻohe Bay. Even on reef sites outside harbors on neighbor islands relatively high numbers could be found, such as 23 species at Marriott Hotel reef on Kauaʻi, or Kaunakakai reef on Molokaʻi, both 1.5 km from harbor piers.

These examples are presented to demonstrate the types of questions that can be determined from simple one step queries of the GIS data files for this project. More complex questions can be posed and answered using multiple sequential queries that further reduce the data set down to specific results relative to the question at hand, which are limited only be the imagination, skill and patience of the GIS user.

9. Internet Access to Marine Introduced Species Information for the Main Hawaiian Islands.

Limited access to GIS-based information can be done interactively on the Internet. However, adapting GIS shapefiles and maps for this process is challenging, and the user interested in accessing the information may not have the training or skills for the relatively complex manipulations required for effective GIS use. An innovative and user-friendly process for accessing the information of this study has been developed by Bishop Museum staff and is available at http://hbs.bishopmuseum.org/invert/invasive.html. This web site allows users to access all of this information using a modification of a Geographic Information System (GIS) analysis adapted to the Google Earth Platform. This provides for easy access to the information with no GIS experience or training required for the user. Google Earth is a free download and works on both Windows and Apple computers. After installing Google Earth, clicking on the Invasive Marine Species of Hawaiʻi link will download a placemark file with the same title. Opening it in Google Earth will then zoom the user to the map shown in Figure 19, with a list of all 157 sites on the taskbar at the left.

Although the Google Earth Version does not provide the capability to make queries, most of the information in the ArcGIS version is easily accessible. Figures 19 to 28 show the processes that are involved and the information that is available. Double clicking on any site listed alphabetically by island in the taskbar (Figure 19) will "fly" the user to that site and show a popup window indicating the total number of species at that site, in this case the Iroquois Point site with 30 species at Pearl Harbor (Figure 20). The same sequence will result by clicking on the site location on the Figure 19 base map. Clicking on the species message line in the popup window will bring up table (Figure 20) that lists all the species for that and related information, i.e. bar graphs of the numbers of introduced and cryptogenic species and their totals, the higher taxa and family of each species, its status and whether it is considered invasive, the type of survey on which it was recorded, and an image, if available. Clicking on the "Download report" line at the top of the table will send the user to the on-line full report pdf (Figure 22) to learn the details of the survey. Clicking on the image shows a full screen view that can be minimized to the size desired (Figure 23). These popup items can be displayed as part of the page in either landscape or portrait view, or as independent pages by making changes in the Google Earth Tools-Options-Preferences menu.

Clicking on any species listed in the table (Figure 21) will bring up another table (Figure 24) that lists every location and the total number of locations where that species was reported on all studies. Also site-relevant information is provided in this table, i.e. the name of the project the characteristics of the site and its substrate, and the date of the survey. In the example provided *Ascidia sydneiensis* occurred at 52 of the 157 sites. Clicking on the name of first site listed Oahu-Honolulu Harbor-Pier 27) in the table on the taskbar to the left "flies" the user to that site (Figure 25). Clicking on its name on the table lists the species for that site along with species-relevant information (Figure 26) and links to the source report pdf and available images. This process of cycling between the species and can be repeated to obtain information about as many species and sites as the user wishes. Also, if the user is interested in any particular species, clicking on "Species" at the top of any species listing table will bring up a full list of all 217 species encountered on all studies (Figure 27). Clicking on a species, e.g. *Acanthophora spicifera*, will then bring the locations list table (Figure 28).

Conclusion

This GIS-based approach has compiled the information from widely dispersed sources over a ten year period into two data sets that provide the capability to analyze information obtained on introduced species over time and space. We hope that this will provide interested scientists and resource managers with a valuable tool that can be utilized to evaluate the long-term impact of marine introductions and help to effect their control, where appropriate.

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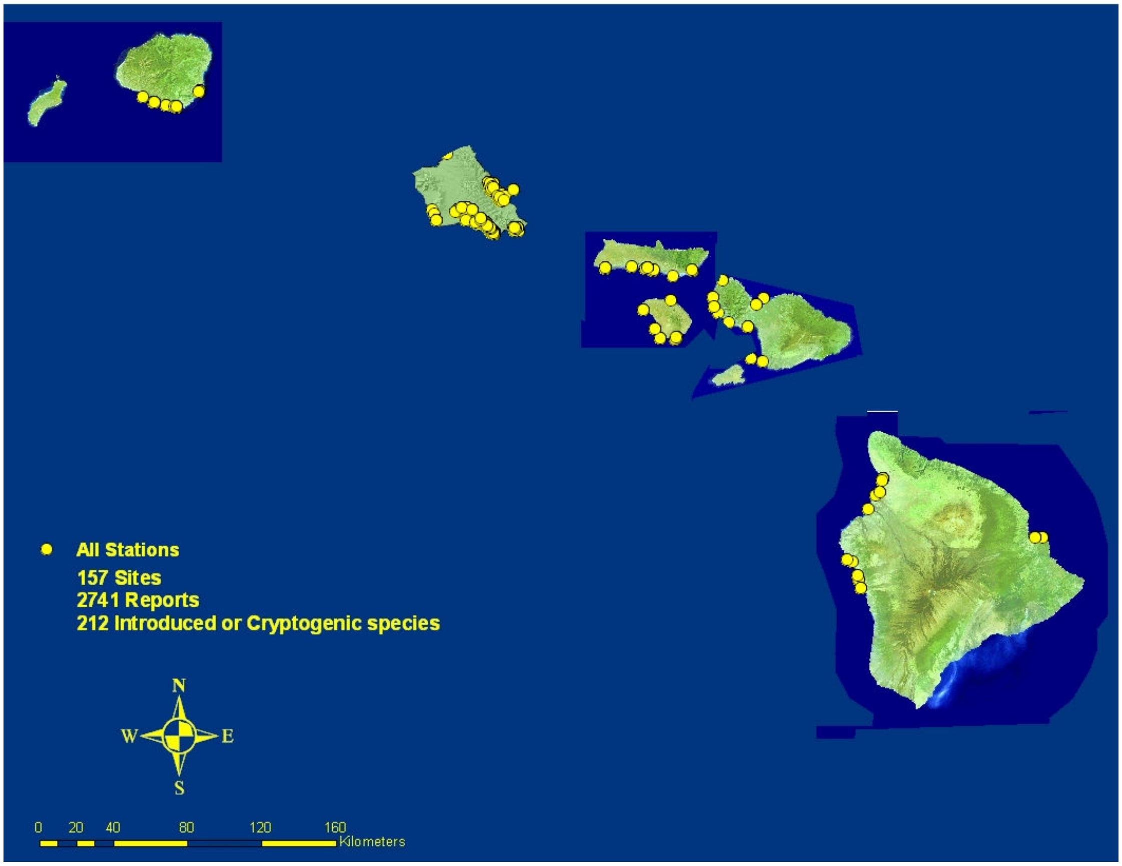
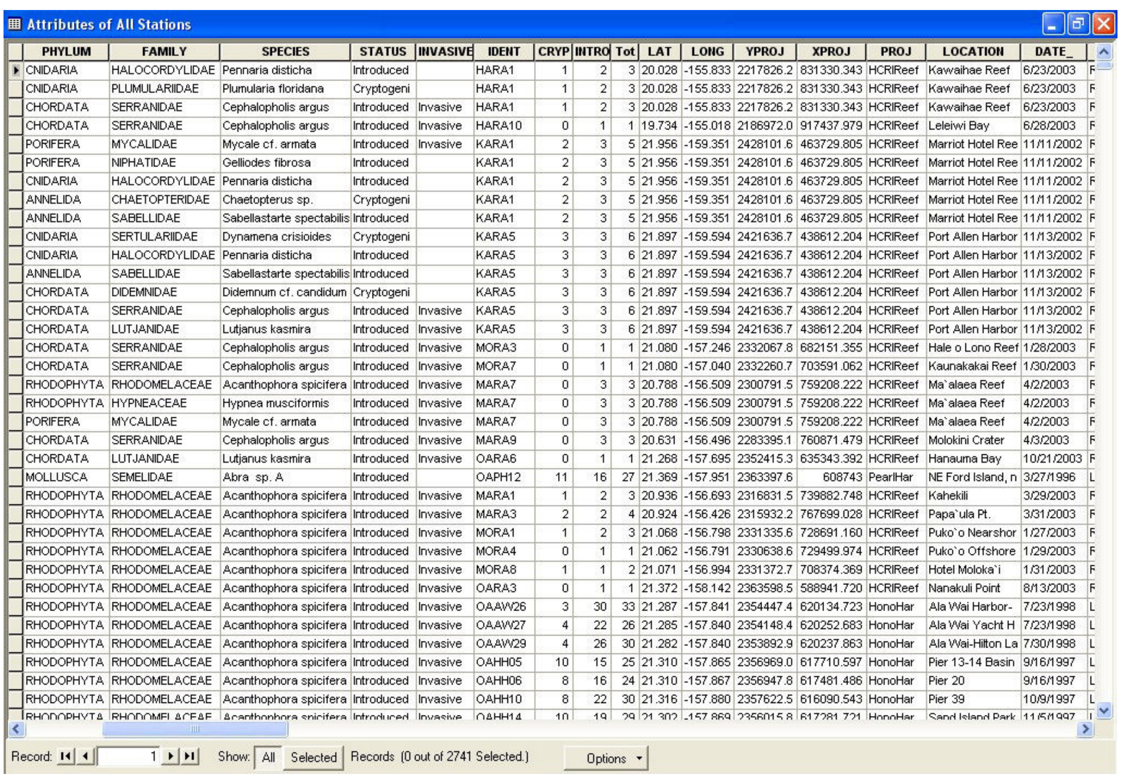


Figure 1. Map of all station locations.



Attributes of All Stations

PHYLUM	FAMILY	SPECIES	STATUS	INVASIVE	IDENT	CRYP	INTRO	Tot	LAT	LONG	YPROJ	XPROJ	PROJ	LOCATION	DATE_	
CNIDARIA	HALOCORDYLIDAE	Pennaria disticha	Introduced		HARA1	1	2	3	20.028	-155.833	2217826.2	831330.343	HCRIReef	Kawaihae Reef	6/23/2003	F
CNIDARIA	PLUMULARIIDAE	Plumularia floridana	Cryptogeni		HARA1	1	2	3	20.028	-155.833	2217826.2	831330.343	HCRIReef	Kawaihae Reef	6/23/2003	F
CHORDATA	SERRANIDAE	Cephalopholis argus	Introduced	Invasive	HARA1	1	2	3	20.028	-155.833	2217826.2	831330.343	HCRIReef	Kawaihae Reef	6/23/2003	F
CHORDATA	SERRANIDAE	Cephalopholis argus	Introduced	Invasive	HARA10	0	1	1	19.734	-155.018	2186972.0	917437.979	HCRIReef	Leleiwi Bay	6/28/2003	F
PORIFERA	MYCALIDAE	Mycale cf. armata	Introduced	Invasive	KARA1	2	3	5	21.956	-159.351	2428101.6	463729.805	HCRIReef	Marriot Hotel Ree	11/11/2002	F
PORIFERA	NIPHATIDAE	Gelliodes fibrosa	Introduced		KARA1	2	3	5	21.956	-159.351	2428101.6	463729.805	HCRIReef	Marriot Hotel Ree	11/11/2002	F
CNIDARIA	HALOCORDYLIDAE	Pennaria disticha	Introduced		KARA1	2	3	5	21.956	-159.351	2428101.6	463729.805	HCRIReef	Marriot Hotel Ree	11/11/2002	F
ANNELIDA	CHAETOPTERIDAE	Chaetopterus sp.	Cryptogeni		KARA1	2	3	5	21.956	-159.351	2428101.6	463729.805	HCRIReef	Marriot Hotel Ree	11/11/2002	F
ANNELIDA	SABELLIDAE	Sabellastarte spectabilis	Introduced		KARA1	2	3	5	21.956	-159.351	2428101.6	463729.805	HCRIReef	Marriot Hotel Ree	11/11/2002	F
CNIDARIA	SERTULARIIDAE	Dynamena crisioides	Cryptogeni		KARA5	3	3	6	21.897	-159.594	2421636.7	438612.204	HCRIReef	Port Allen Harbor	11/13/2002	F
CNIDARIA	HALOCORDYLIDAE	Pennaria disticha	Introduced		KARA5	3	3	6	21.897	-159.594	2421636.7	438612.204	HCRIReef	Port Allen Harbor	11/13/2002	F
ANNELIDA	SABELLIDAE	Sabellastarte spectabilis	Introduced		KARA5	3	3	6	21.897	-159.594	2421636.7	438612.204	HCRIReef	Port Allen Harbor	11/13/2002	F
CHORDATA	DIDEMNIDAE	Didemnum cf. candidum	Cryptogeni		KARA5	3	3	6	21.897	-159.594	2421636.7	438612.204	HCRIReef	Port Allen Harbor	11/13/2002	F
CHORDATA	SERRANIDAE	Cephalopholis argus	Introduced	Invasive	KARA5	3	3	6	21.897	-159.594	2421636.7	438612.204	HCRIReef	Port Allen Harbor	11/13/2002	F
CHORDATA	LUTJANIDAE	Lutjanus kasmira	Introduced	Invasive	KARA5	3	3	6	21.897	-159.594	2421636.7	438612.204	HCRIReef	Port Allen Harbor	11/13/2002	F
CHORDATA	SERRANIDAE	Cephalopholis argus	Introduced	Invasive	MORA3	0	1	1	21.080	-157.246	2332067.8	682151.355	HCRIReef	Hale o Lono Reef	1/28/2003	F
CHORDATA	SERRANIDAE	Cephalopholis argus	Introduced	Invasive	MORA7	0	1	1	21.080	-157.040	2332260.7	703591.062	HCRIReef	Kaunakakai Reef	1/30/2003	F
RHODOPHYTA	RHODOMELACEAE	Acanthophora spicifera	Introduced	Invasive	MARA7	0	3	3	20.788	-156.509	2300791.5	759208.222	HCRIReef	Ma`alaea Reef	4/2/2003	F
RHODOPHYTA	HYPNEACEAE	Hypnea musciformis	Introduced	Invasive	MARA7	0	3	3	20.788	-156.509	2300791.5	759208.222	HCRIReef	Ma`alaea Reef	4/2/2003	F
PORIFERA	MYCALIDAE	Mycale cf. armata	Introduced	Invasive	MARA7	0	3	3	20.788	-156.509	2300791.5	759208.222	HCRIReef	Ma`alaea Reef	4/2/2003	F
CHORDATA	SERRANIDAE	Cephalopholis argus	Introduced	Invasive	MARA9	0	3	3	20.631	-156.496	2283395.1	760871.479	HCRIReef	Molokini Crater	4/3/2003	F
CHORDATA	LUTJANIDAE	Lutjanus kasmira	Introduced	Invasive	OARA6	0	1	1	21.268	-157.695	2352415.3	635343.392	HCRIReef	Hanauma Bay	10/21/2003	F
MOLLUSCA	SEMELIDAE	Abra sp. A	Introduced		OAPH12	11	16	27	21.369	-157.951	2363397.6	608743	PearlHar	NE Ford Island, n	3/27/1996	L
RHODOPHYTA	RHODOMELACEAE	Acanthophora spicifera	Introduced	Invasive	MARA1	1	2	3	20.936	-156.693	2316831.5	739882.748	HCRIReef	Kahekili	3/29/2003	F
RHODOPHYTA	RHODOMELACEAE	Acanthophora spicifera	Introduced	Invasive	MARA3	2	2	4	20.924	-156.426	2315932.2	767699.028	HCRIReef	Papa`ula Pt.	3/31/2003	F
RHODOPHYTA	RHODOMELACEAE	Acanthophora spicifera	Introduced	Invasive	MORA1	1	2	3	21.068	-156.798	2331335.6	728691.160	HCRIReef	Puko`o Nearshor	1/27/2003	F
RHODOPHYTA	RHODOMELACEAE	Acanthophora spicifera	Introduced	Invasive	MORA4	0	1	1	21.062	-156.791	2330638.6	729499.974	HCRIReef	Puko`o Offshore	1/29/2003	F
RHODOPHYTA	RHODOMELACEAE	Acanthophora spicifera	Introduced	Invasive	MORA8	1	1	2	21.071	-156.994	2331372.7	708374.369	HCRIReef	Hotel Moloka`i	1/31/2003	F
RHODOPHYTA	RHODOMELACEAE	Acanthophora spicifera	Introduced	Invasive	OARA3	0	1	1	21.372	-158.142	2363598.5	588941.720	HCRIReef	Nanakuli Point	8/13/2003	F
RHODOPHYTA	RHODOMELACEAE	Acanthophora spicifera	Introduced	Invasive	OAAW26	3	30	33	21.287	-157.841	2354447.4	620134.723	HonoHar	Ala Wai Harbor-	7/23/1998	L
RHODOPHYTA	RHODOMELACEAE	Acanthophora spicifera	Introduced	Invasive	OAAW27	4	22	26	21.285	-157.840	2354148.4	620252.683	HonoHar	Ala Wai Yacht H	7/23/1998	L
RHODOPHYTA	RHODOMELACEAE	Acanthophora spicifera	Introduced	Invasive	OAAW29	4	26	30	21.282	-157.840	2353892.9	620237.863	HonoHar	Ala Wai-Hilton La	7/30/1998	L
RHODOPHYTA	RHODOMELACEAE	Acanthophora spicifera	Introduced	Invasive	OAHH05	10	15	25	21.310	-157.865	2356969.0	617710.597	HonoHar	Pier 13-14 Basin	9/16/1997	L
RHODOPHYTA	RHODOMELACEAE	Acanthophora spicifera	Introduced	Invasive	OAHH06	8	16	24	21.310	-157.867	2356947.8	617481.486	HonoHar	Pier 20	9/16/1997	L
RHODOPHYTA	RHODOMELACEAE	Acanthophora spicifera	Introduced	Invasive	OAHH10	8	22	30	21.316	-157.880	2357622.5	616090.543	HonoHar	Pier 39	10/9/1997	L
RHODOPHYTA	RHODOMELACEAE	Acanthophora spicifera	Introduced	Invasive	OAHH14	10	19	29	21.302	-157.869	2356015.8	617281.721	HonoHar	Sand Island Park	11/5/1997	L

Record: 1 Show: All Selected Records (0 out of 2741 Selected.) Options

Figure 2. Attribute table for all species, location and environmental data.

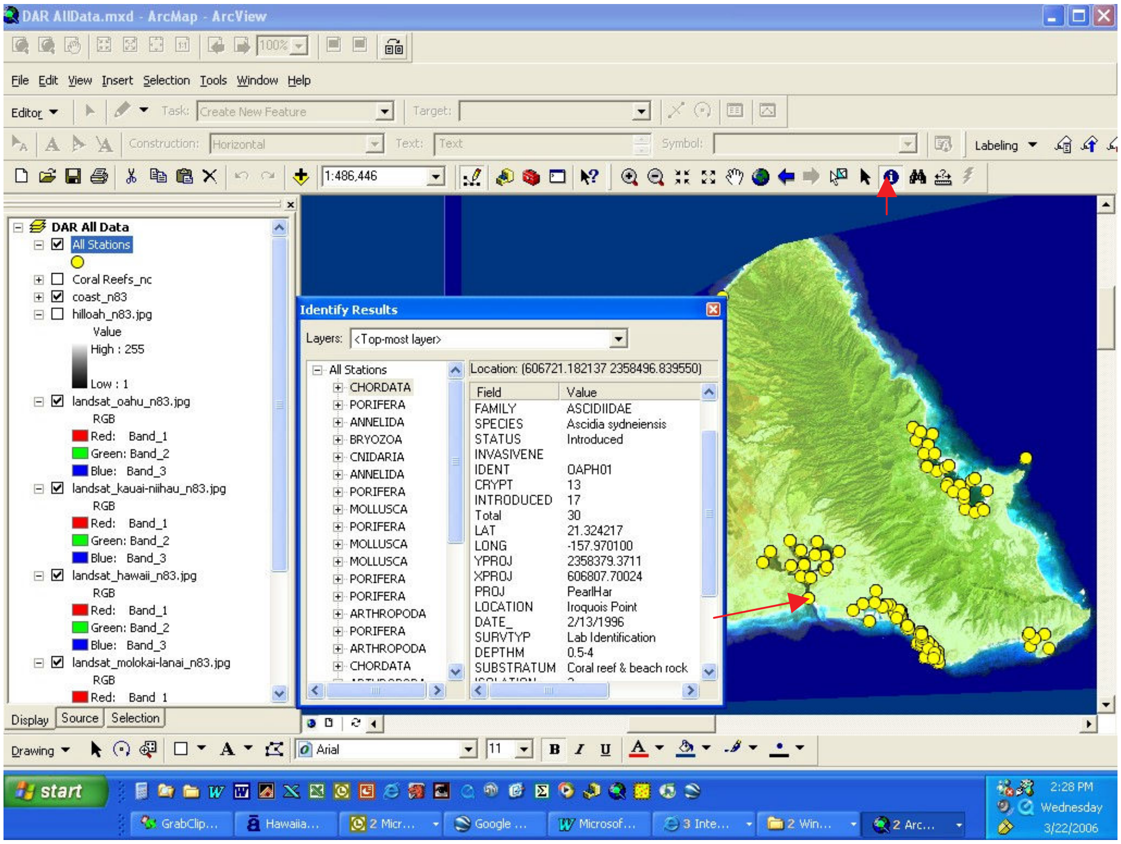


Figure 3. Summary of site characteristics using Identify tool.

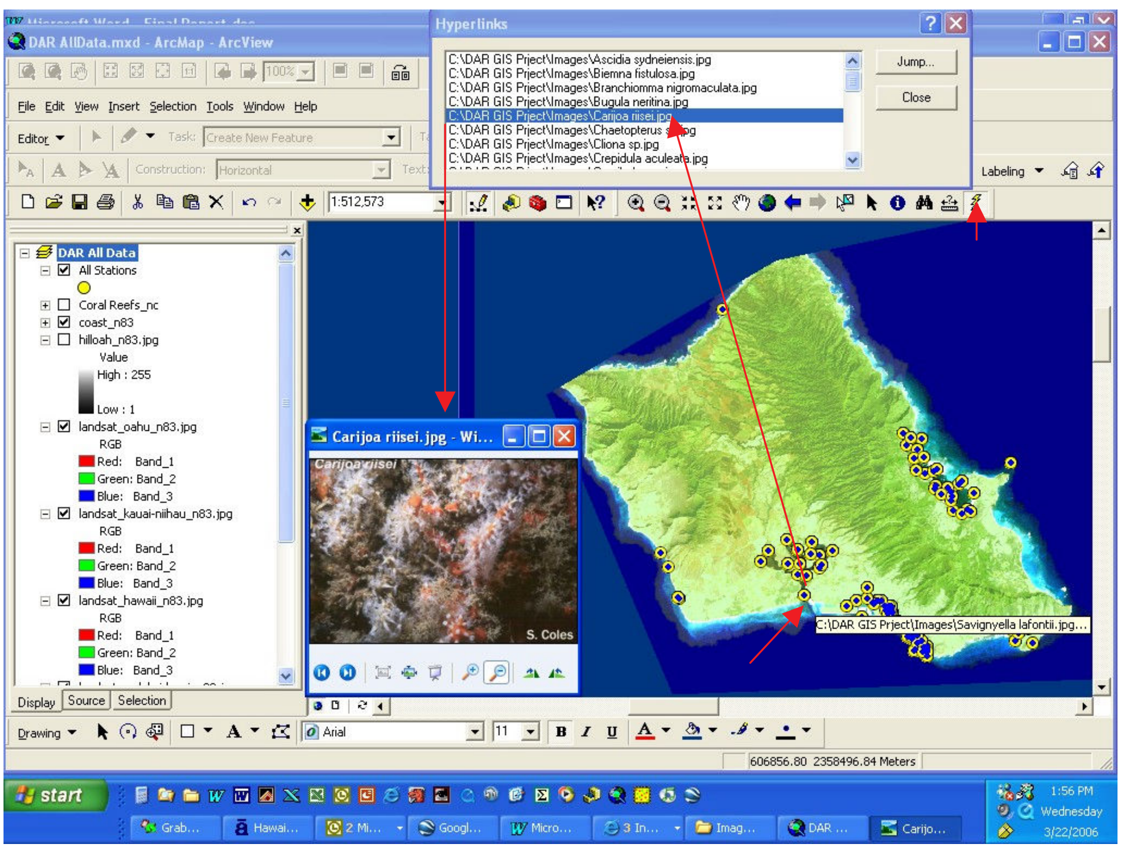


Figure 4. Showing list of species at a site and an image using Hyperlink tool.

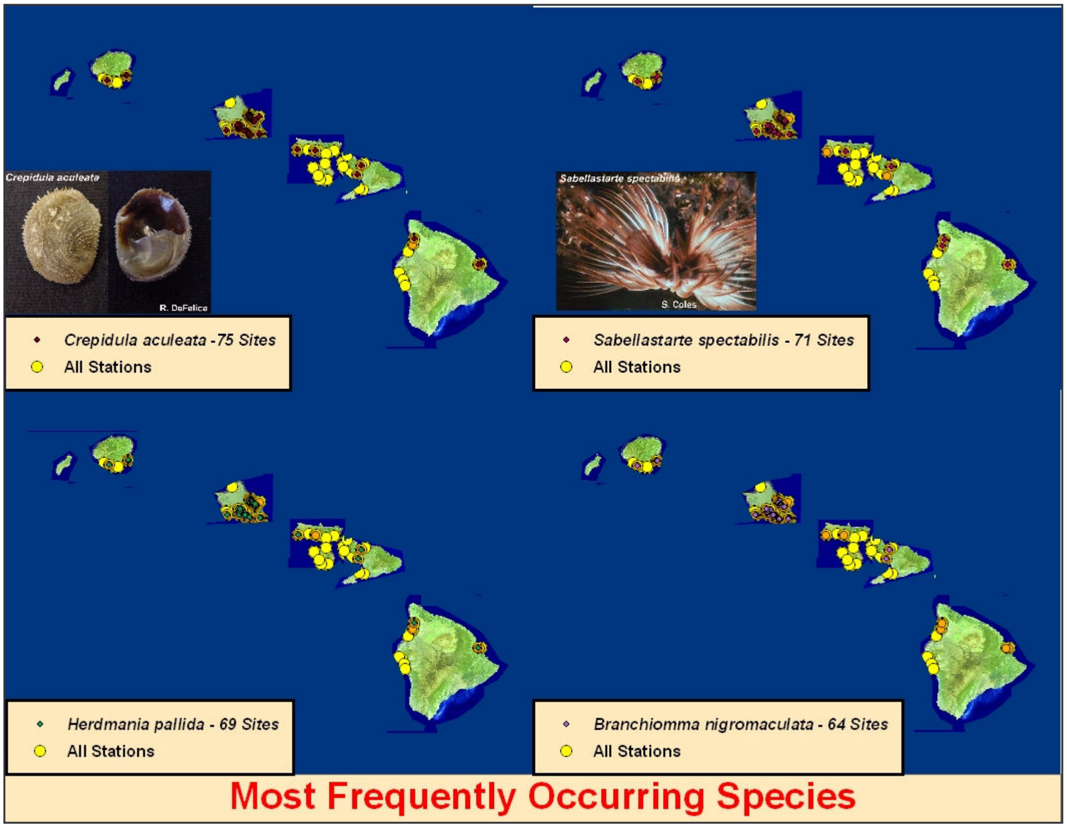


Figure 5. Four most frequently occurring introduced or cryptogenic species.

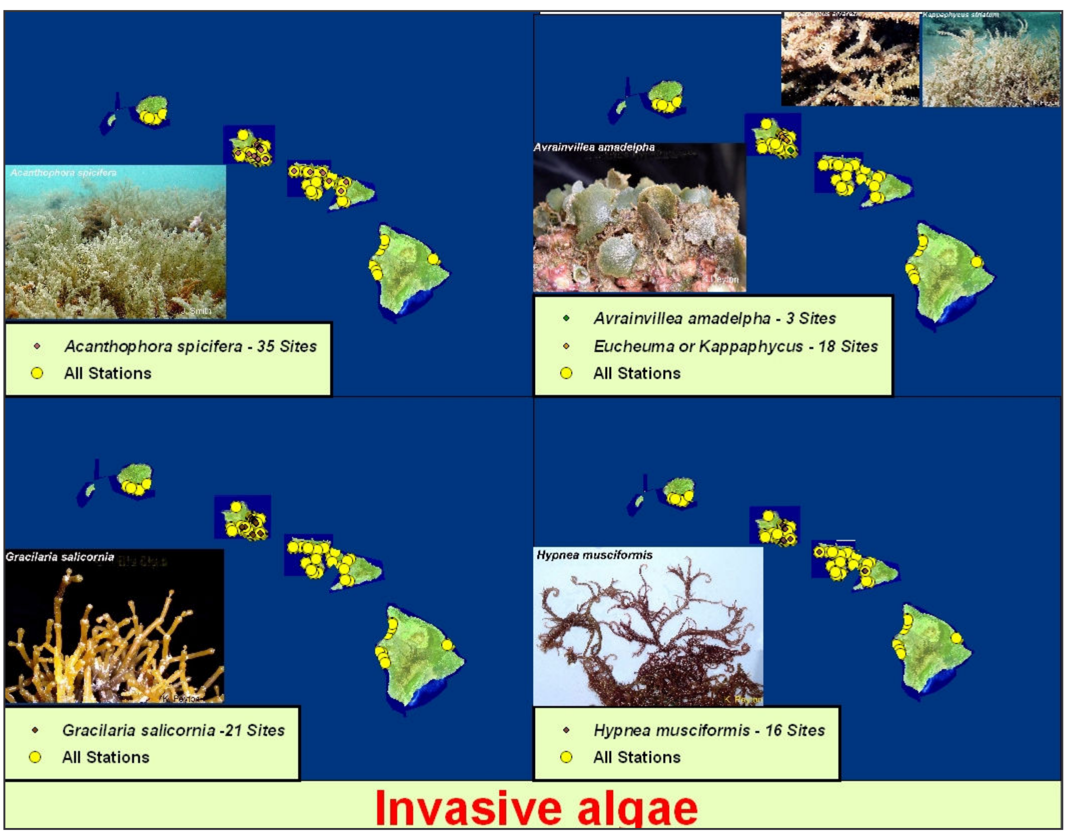


Figure 6. Locations of invasive introduced algal species.

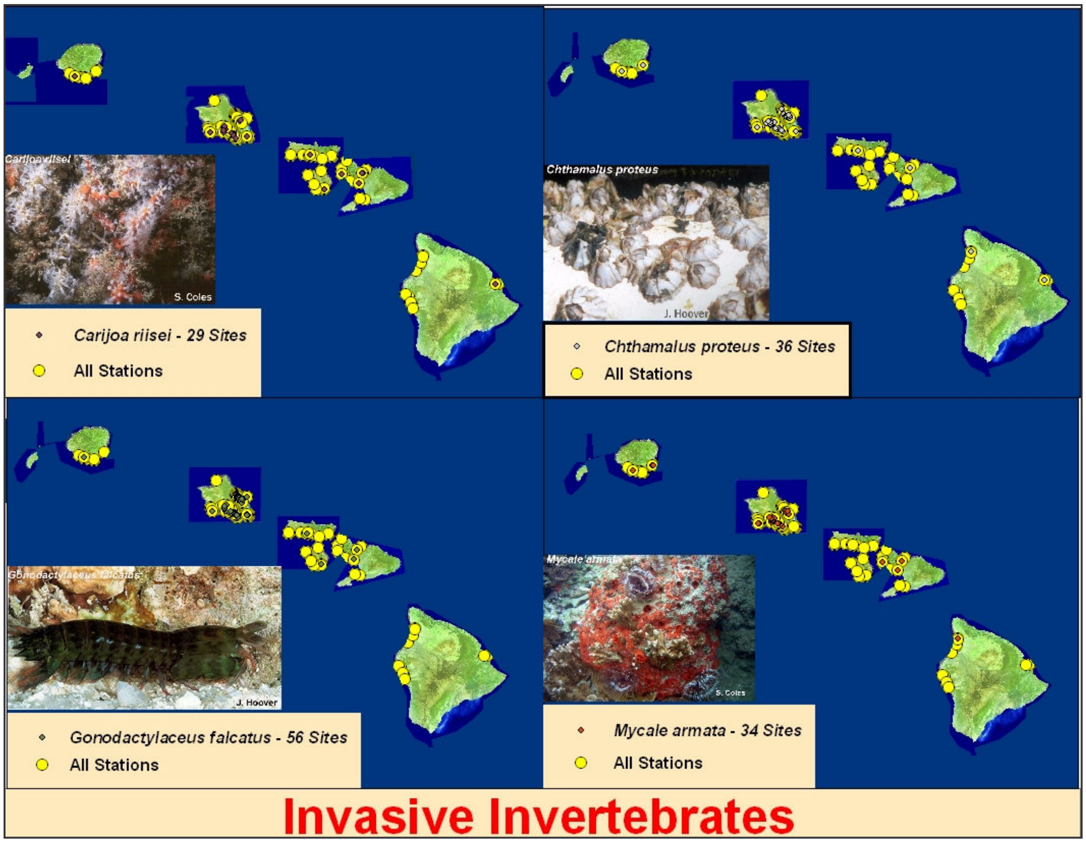


Figure 7. Locations of invasive introduced invertebrate species.

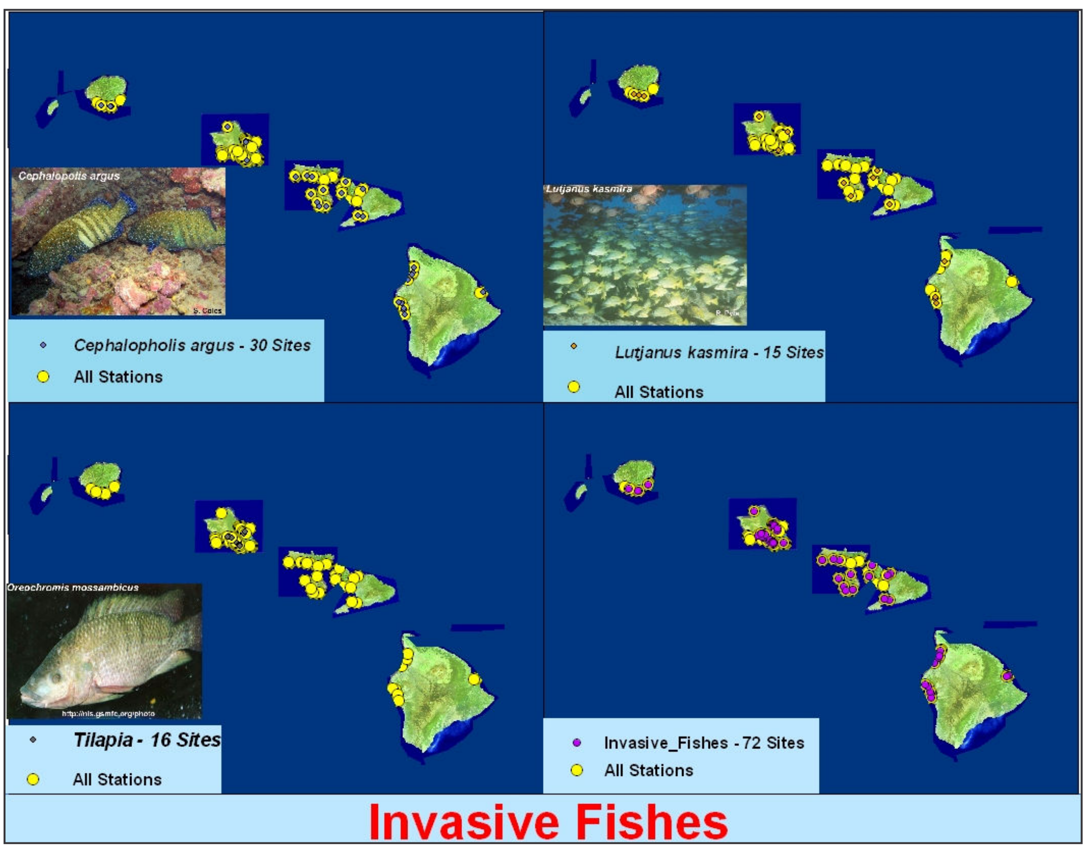


Figure 8. Locations of invasive introduced fish species.

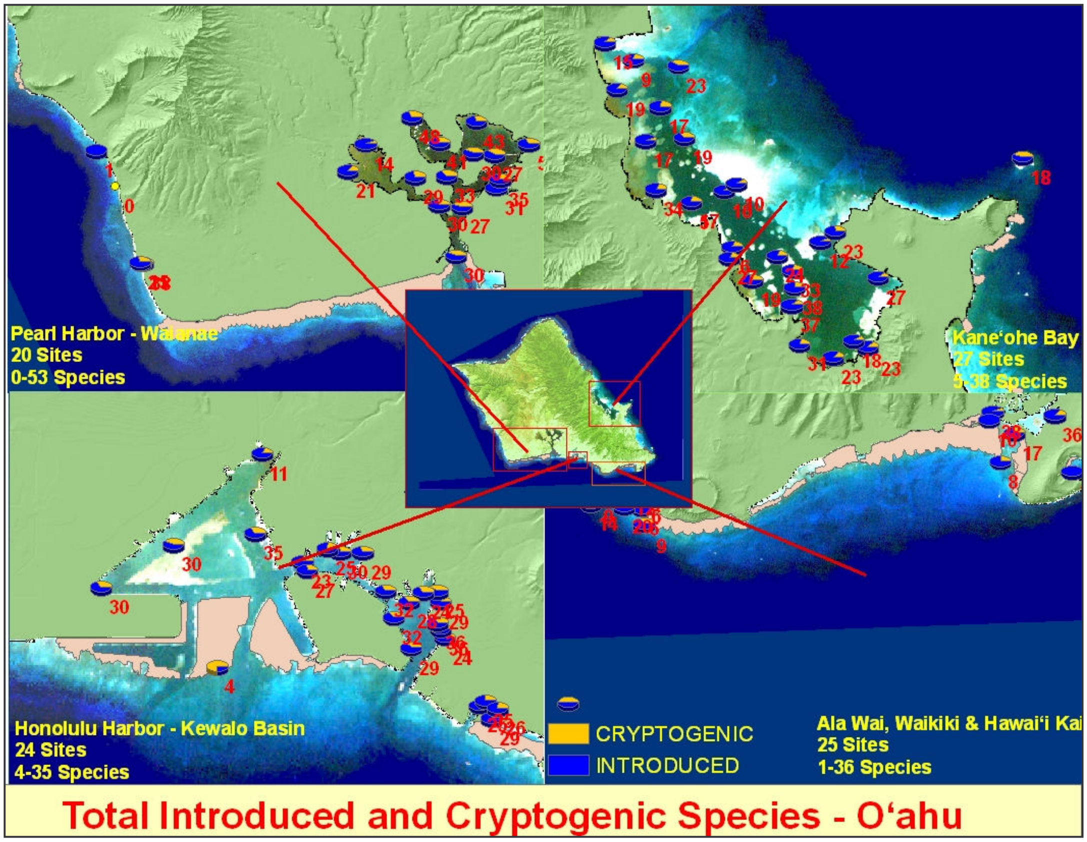


Figure 9. Total introduced and cryptogenic species at O'ahu sites.

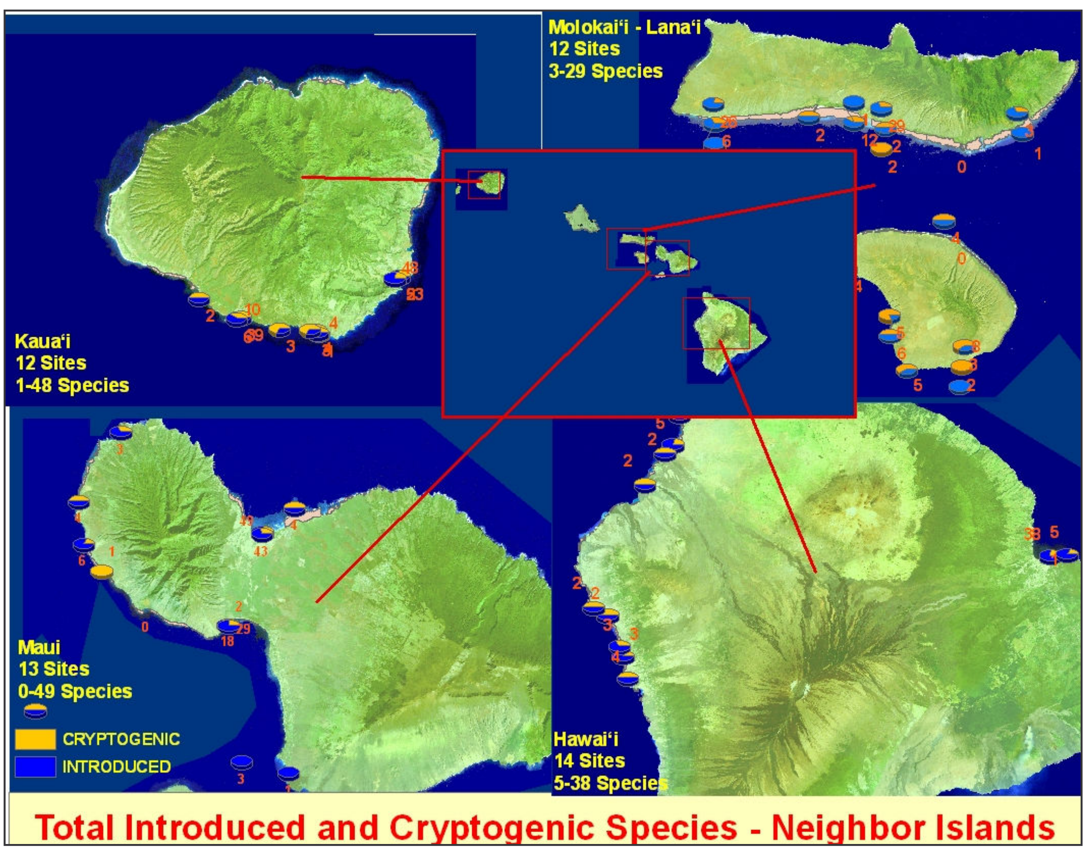


Figure 10. Total introduced and cryptogenic species at Neighbor Island sites.

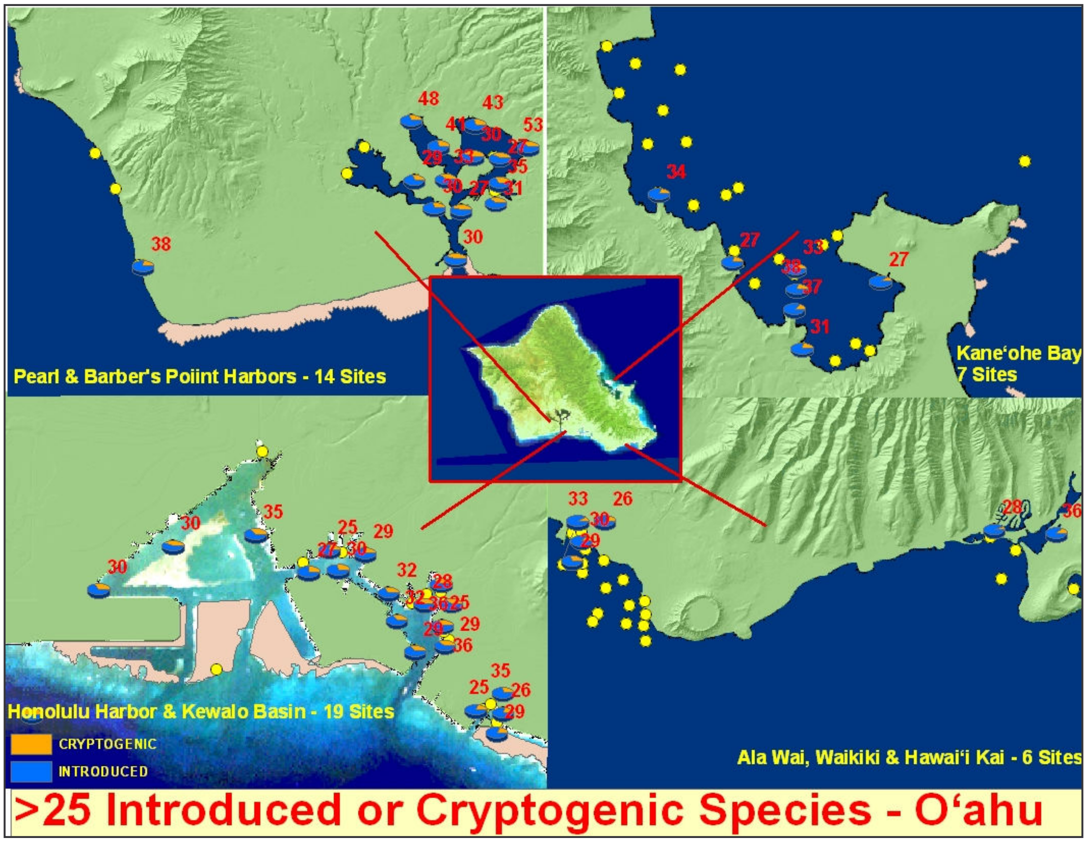


Figure 11. Sites with more than 25 introduced or cryptogenic species on Oahu.

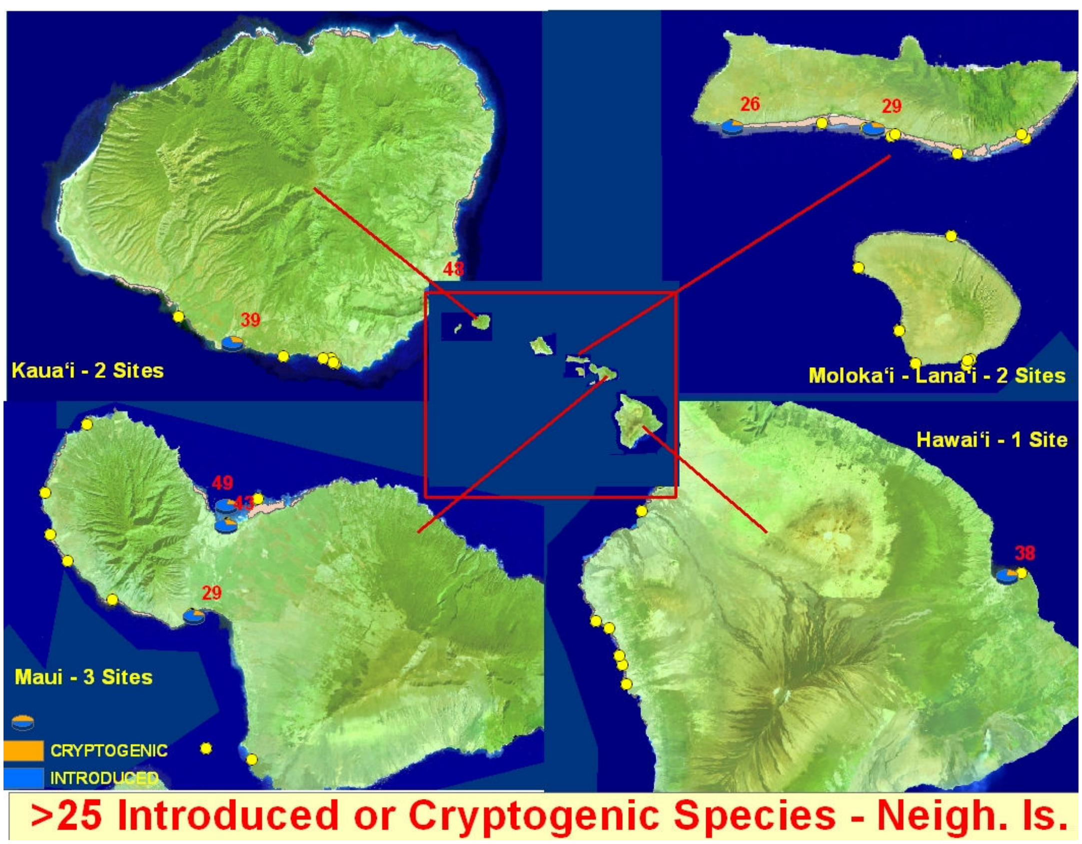


Figure 12. Sites with more than 25 introduced or cryptogenic species on Neighbor Islands.

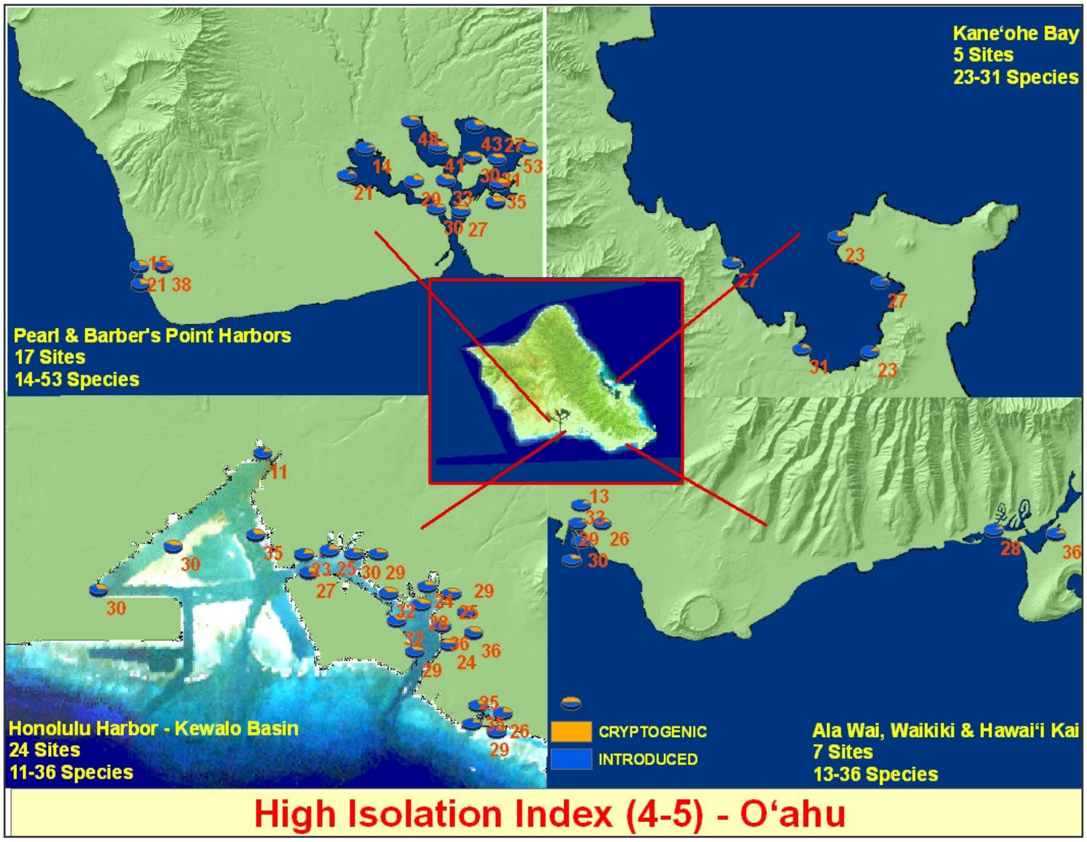


Figure 13. O'ahu sites isolated from open-ocean circulation.

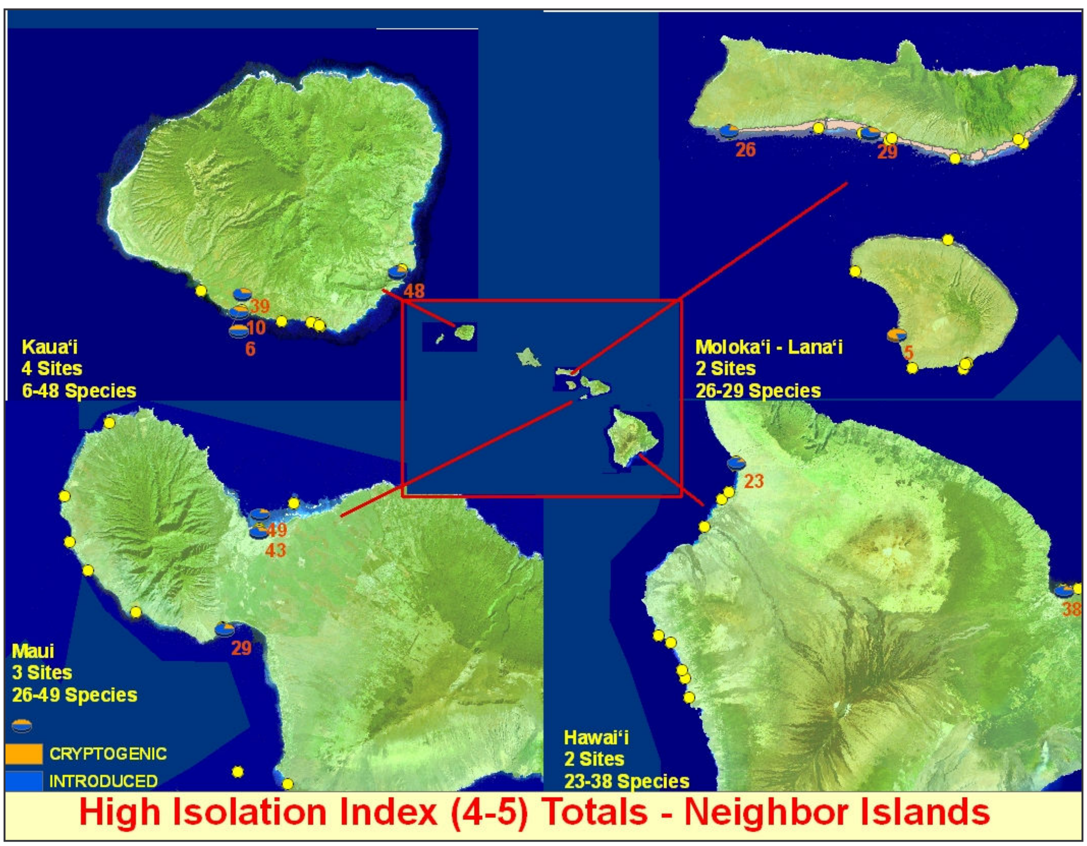


Figure 14. Neighbor Island sites isolated from open ocean circulation.

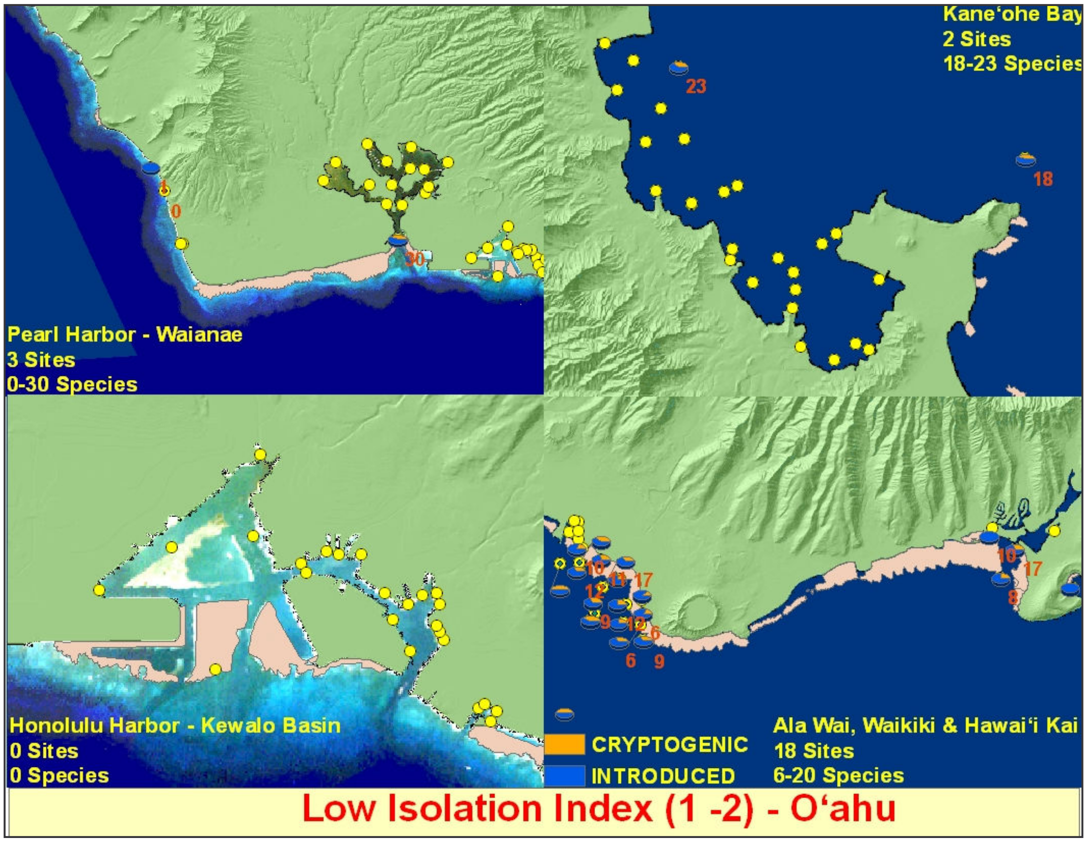


Figure 15. O'ahu sites exposed to open ocean circulation.

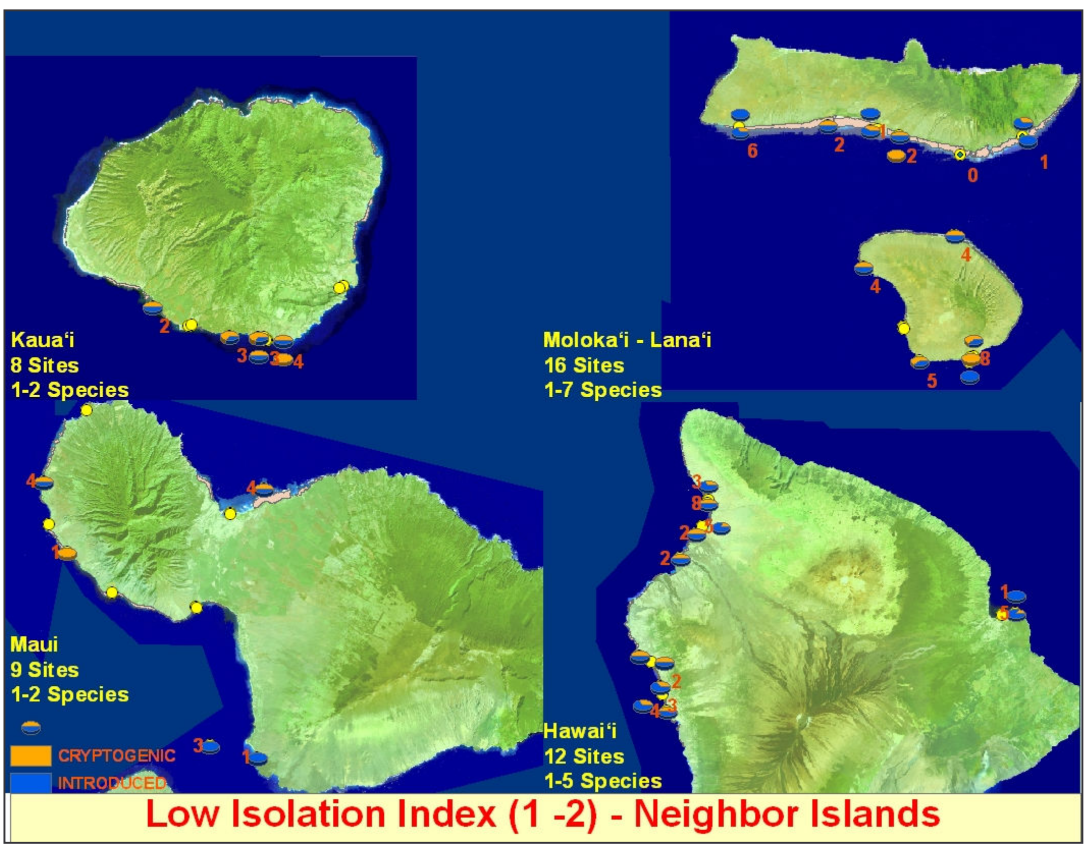


Figure 16. Neighbor Island sites exposed to open ocean circulation.

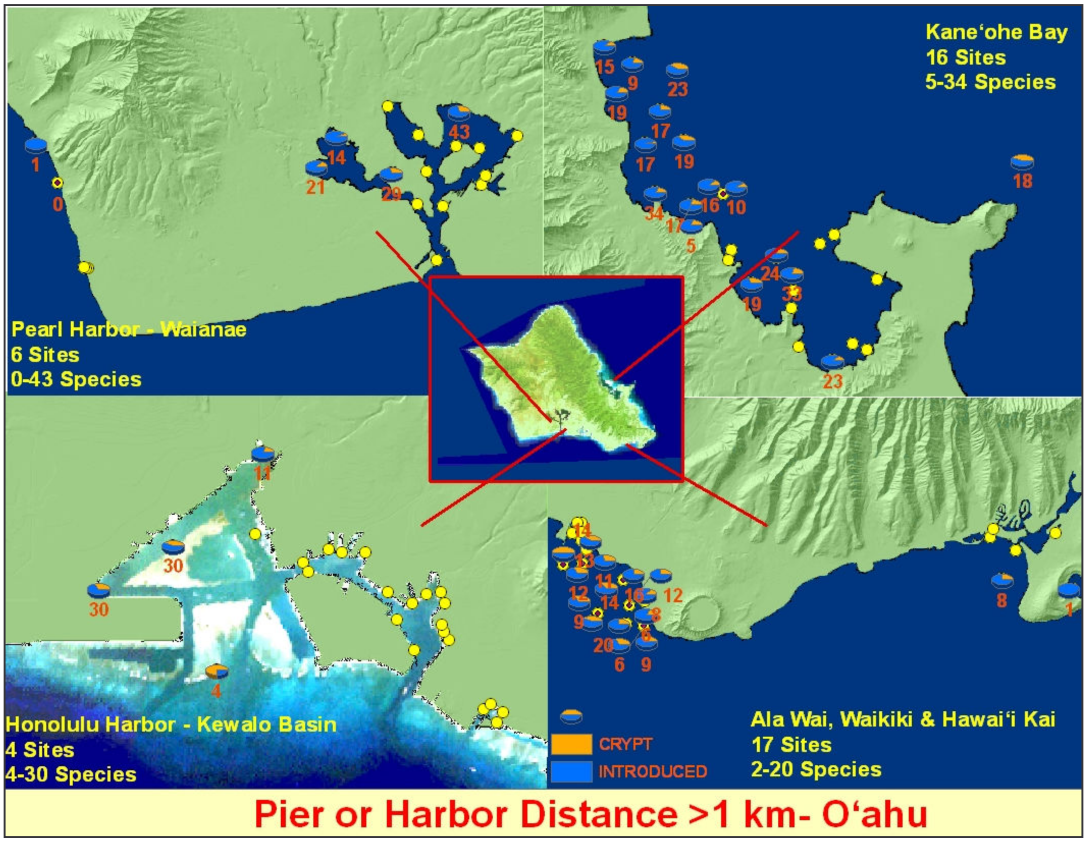


Figure 17. O'ahu sites greater than 1 km from a harbor or a pier within a harbor.

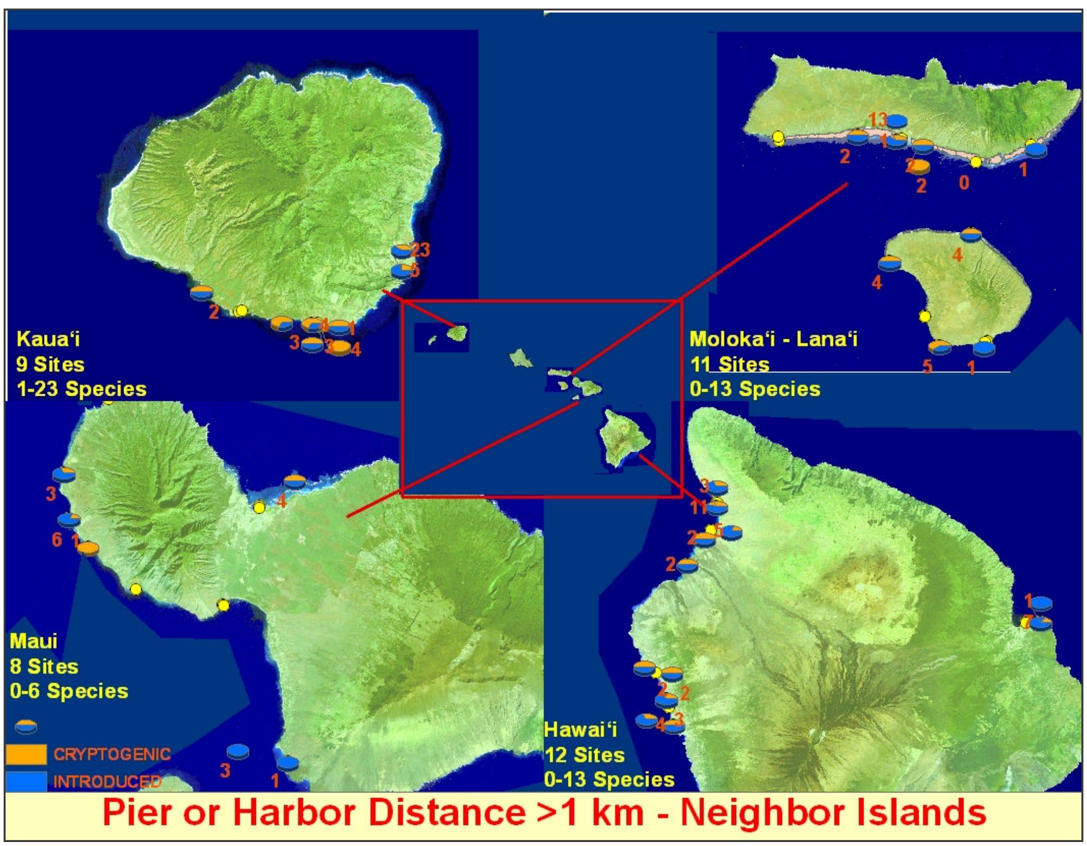


Figure 18. Neighbor Island sites greater than 1 km from a harbor or a pier within a harbor.

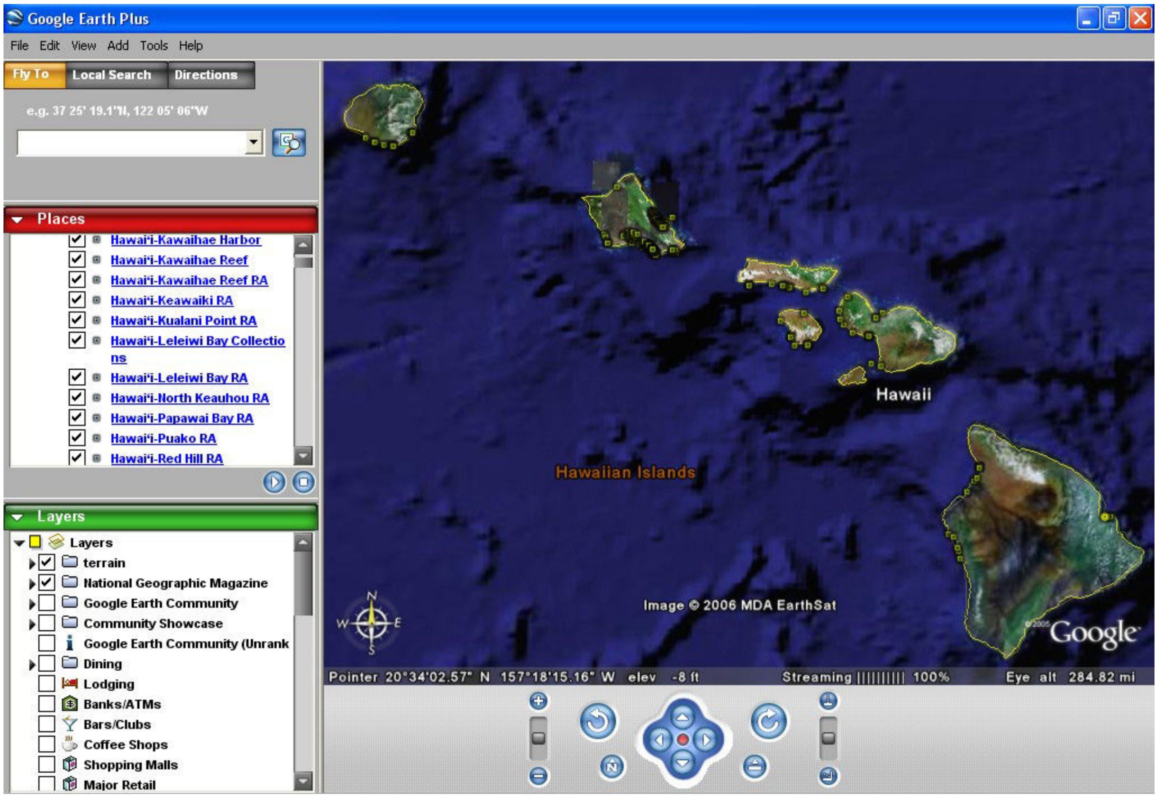


Figure 19. Google Earth Base map for Main Hawaiian Islands Marine Introduced Species data.

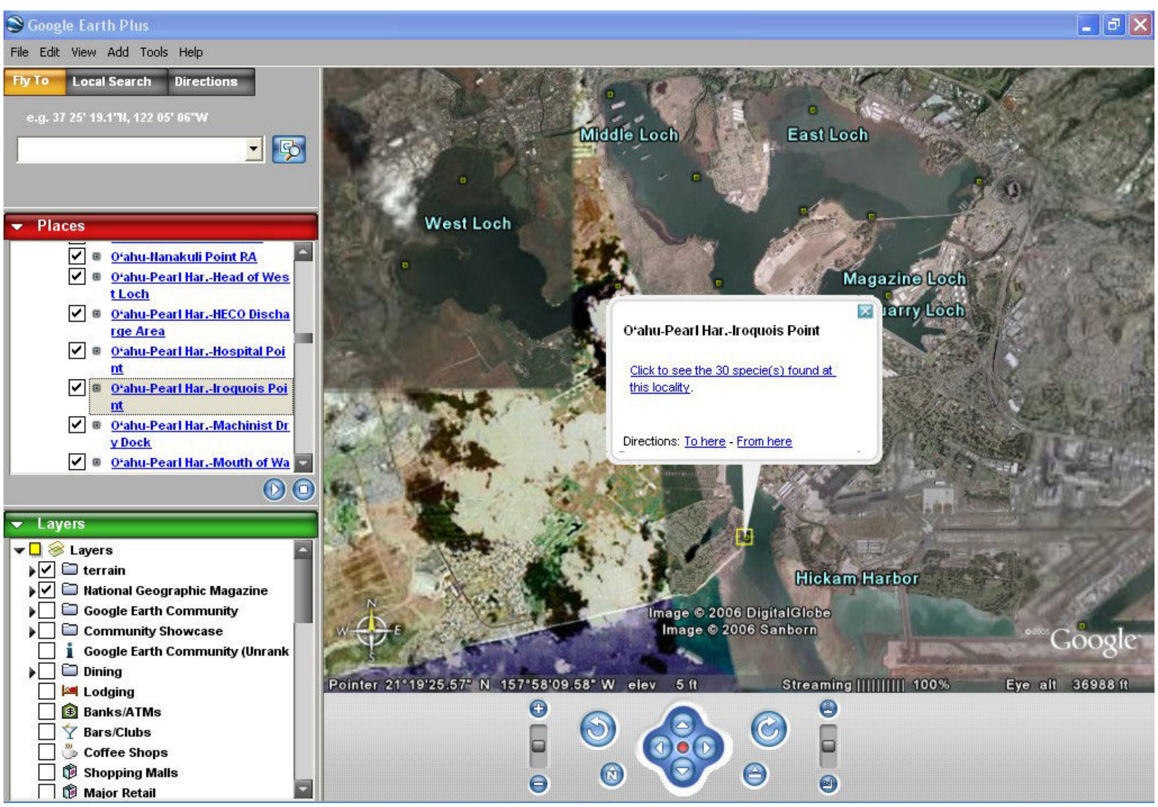


Figure 20. Map zoomed to O'ahu Pearl Harbor Iroquois Point site.

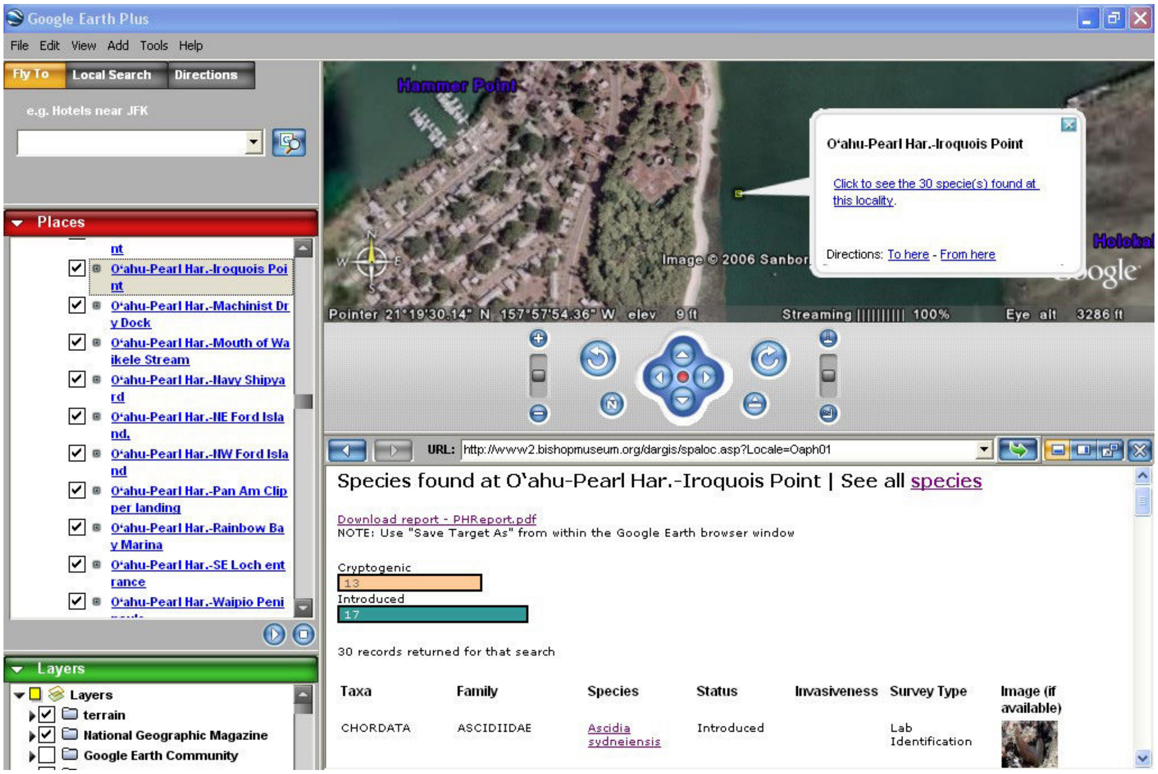


Figure 21 Species table associated with Iroquois point site.

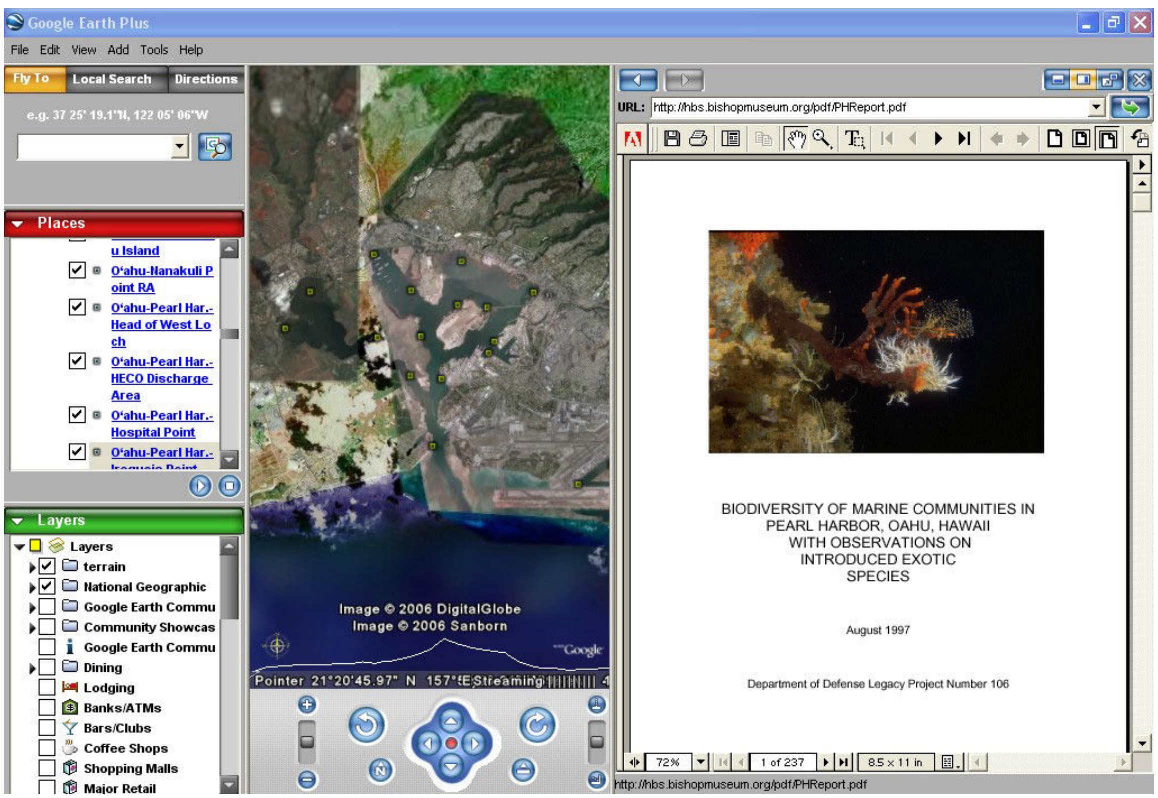


Figure 22. Species table associated with Iroquois point site.

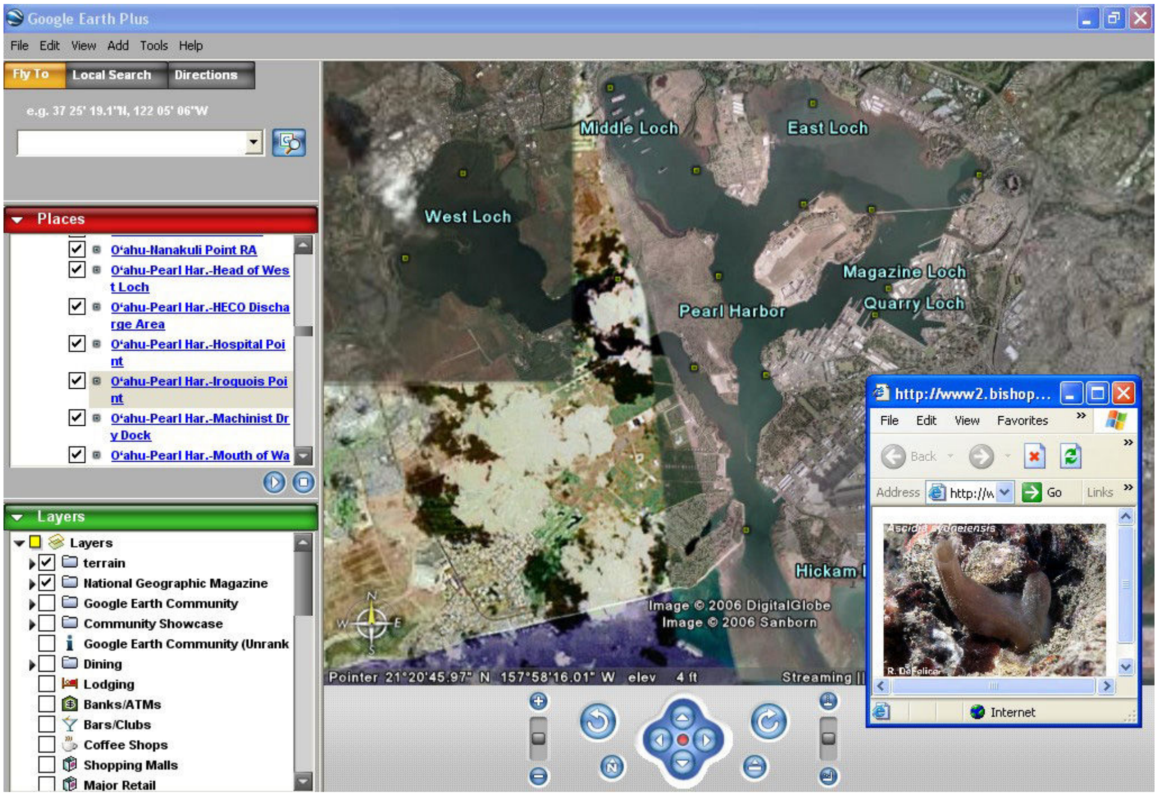


Figure 23. Image of *Ascidia sydneiensis*.

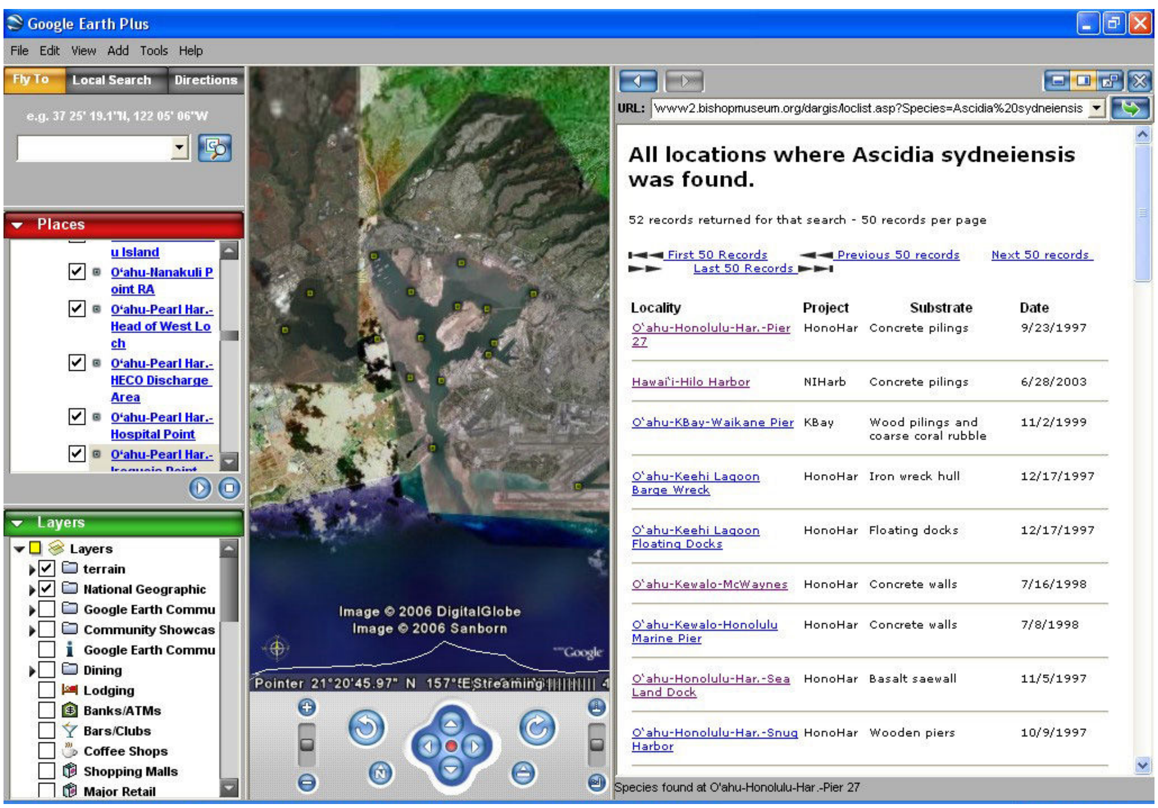


Figure 24. List of sites where *Ascidia sydneiensis* occurred.

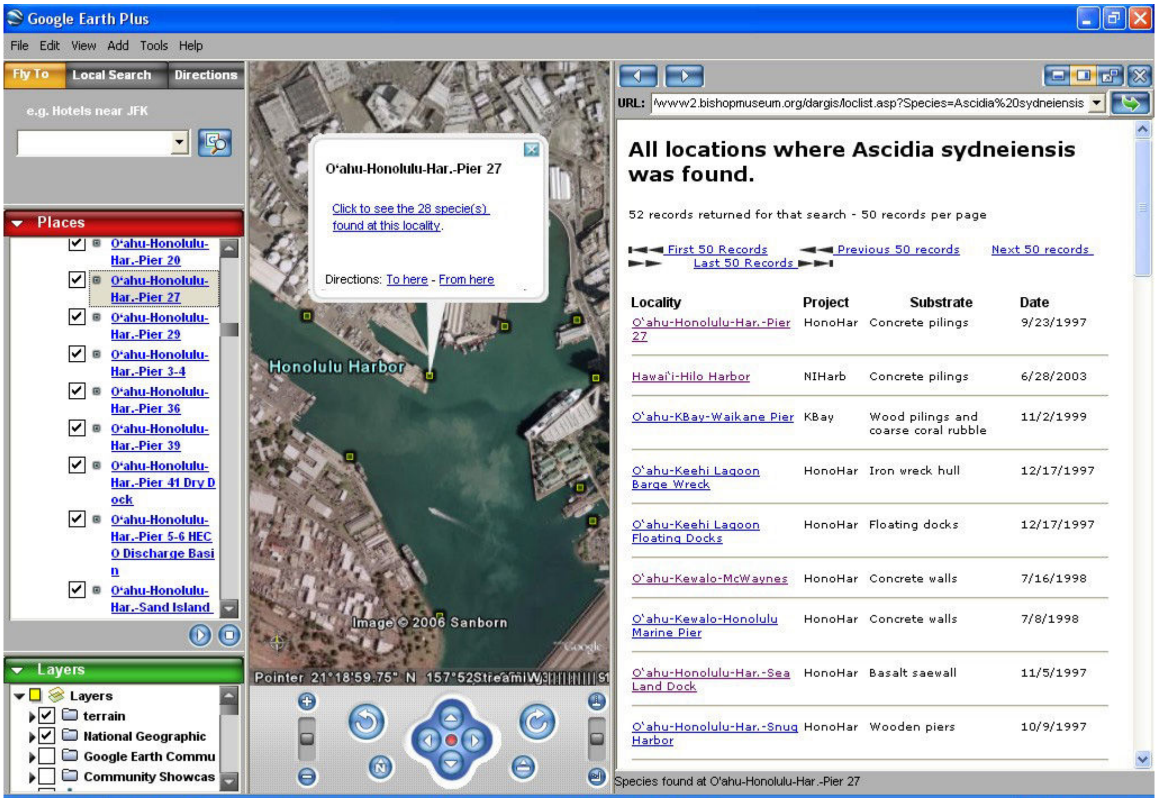


Figure 25. Map zoomed to the first site in the list for *Ascidia sydneiensis*, Honolulu Harbor–Pier 27.

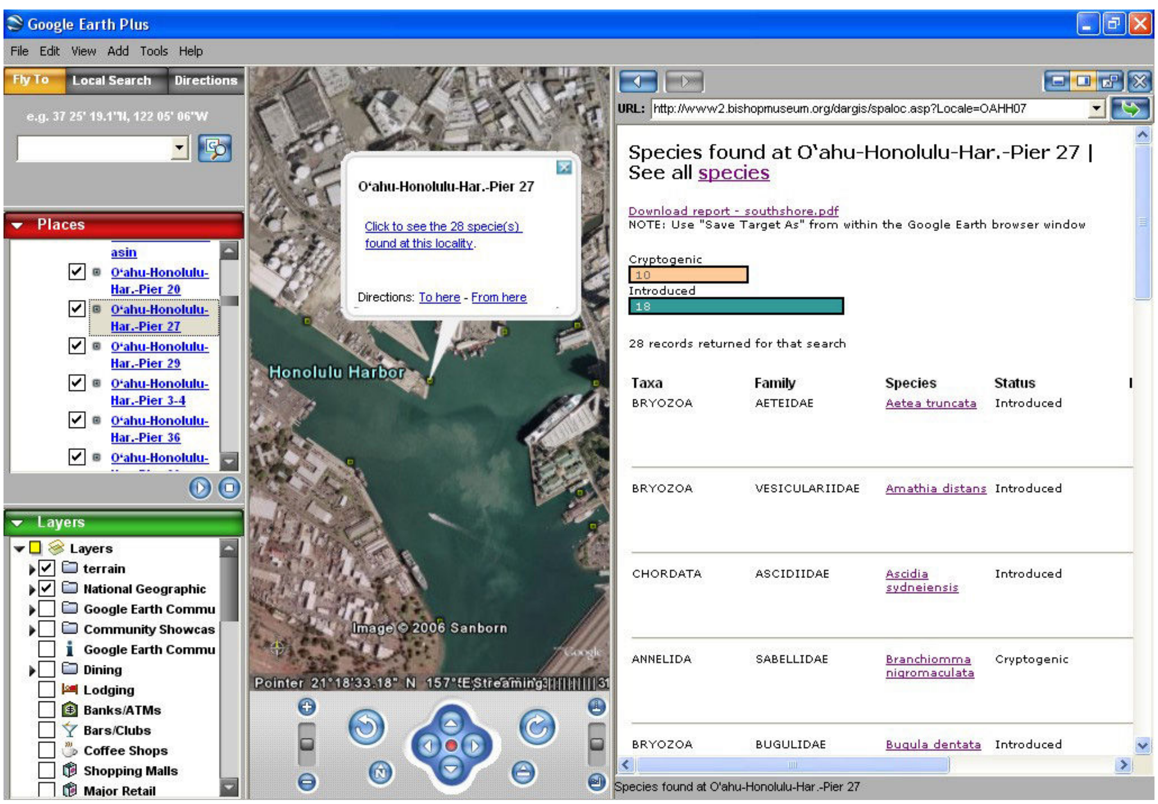


Figure 26. List of other species occurring at Honolulu Harbor–Pier 27.

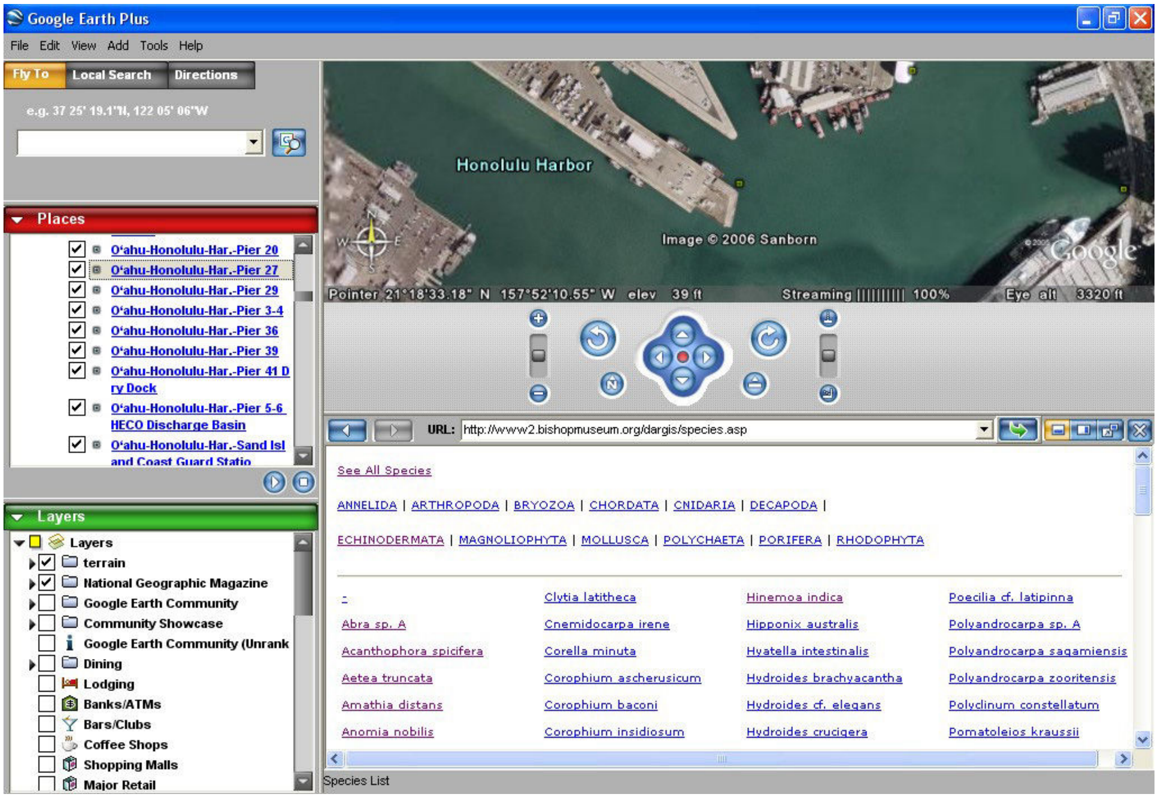


Figure 27. List of all species in the database.

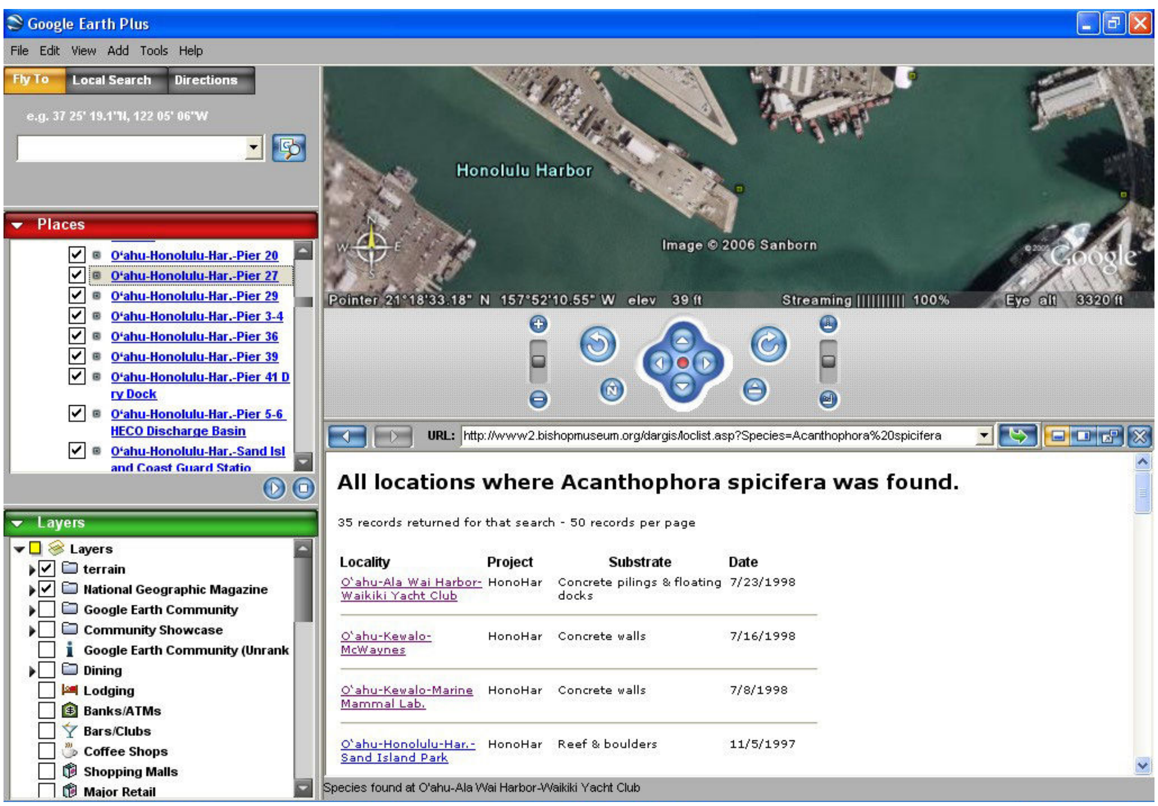


Figure 28. Locations where *Acanthophora spicifera* occurred.