Aquatic Invasive Species Vector Risk Assessments:

An Analysis of Aquaculture as a Vector for Introduced Marine and Estuarine Species in California

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By:

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Executive Summary

The aquaculture industry has contributed substantially to the economic base of many areas in coastal California. At the same time it has also contributed significantly to the total number of non-native species, particularly in bays and estuaries where aquaculture production is present. Aquaculture practices are now dramatically different than they were historically regarding the importation of non-native species either intentionally as a focal aquaculture species, or unintentionally as a hitchhiker with aquaculture shipments. However, aquaculture still poses an unknown, poorly quantified risk with regard to the introduction, establishment, and spread of non-indigenous species (NIS). Thus, the main objective of this report was to describe and characterize the risk posed by marine aquaculture as a vector for the NIS in the marine and estuarine waters of California.

Our ***Key Findings*** (highlighted similarly within Results section) are:

- During the period for which data are available (1853-2011), 126 non-native species associated with aquaculture have been introduced into California
- Of these 126 species, 106 are documented as having successfully become established following introduction
- The majority of first introductions (86 species) were in San Francisco Bay
- Nearly all of the first records of introduction were sites from Monterey Bay northward
- Most of these species are found in locations in which aquaculture activities historically occurred and/or currently occur, however, 24 locations throughout state, including some coastal areas, also have these species
- The number of species being imported into California for aquaculture purposes has declined over the last twenty years
- Over the same period of time, the number of permits for importing non-native species into California has slightly increased
- The current permitting process in California does not allow:
    - an accurate assessment of either the number of species or the quantity of any one species currently cultured in the state
    - an accounting of number of species or the quantity of any one species that is being imported into the state for aquaculture purposes
    - an accounting for any species being moved between bays within the state
    - an assessment of the degree to which triploid oysters (vs. diploid) are being cultured in the state
- Non-native species that are not established in California are both permitted for release and are being brought into the state
- The permitting process for species in aquaculture is complicated and may require multiple permits from multiple state and federal agencies
- There is no central source of information on either the quantity or identity of aquaculture species, the regulations that apply to aquaculture, or the permits required

- Impacts of non-indigenous seaweeds and molluscs are poorly-studied (~25% of peer-reviewed publications focusing on these species measure, or conduct experiments on impacts)

We vigorously recommend that the current permitting process be streamlined and centralized with a single permit for all aquaculture activities that would be recognized by all authorizing agencies. This would facilitate a centralized and coordinated data base that would bring together relevant permit data and also allow more accurate and complete data management and dissemination. We also recommend greater detail be provided in this permitting process with respect to species identification, quantities imported and other information that is not currently required or inadequately reported.

The collective conclusion of colleagues investigating other vectors (ornamental trades, fishing and recreational vessels, live seafood and bait) that we currently do not have sufficient data to assess the risks posed by these vectors for introducing non-native species into California. As a consequence, we strongly recommendation that California engage in a quantitative cross-vector assessment for marine non-indigenous species. A vector-based management approach is widely acknowledged as the most cost-effective means of reducing the future risk of non-indigenous species introductions, however, this cannot be developed without a comprehensive cross-vector analysis.

1.0 Introduction

The aquaculture industry has been and continues to be a cornerstone of economic activity in many bays and estuaries in California. Aquaculture began in earnest in the 1850s, involving the culture and harvest of shellfish and finfish species many of which were non-native, having been imported from around the world. Many of those species originally imported still remain in California waters. Current aquaculture practices have greatly reduced the number of non-native species entering California via this vector. However, non-native species continue to enter California via aquaculture practices together with "hitchhiking" associated species, including parasites and pathogens.

Historically, the aquaculture industry was responsible for introducing many damaging pests via the movement of aquaculture products. This includes historic introductions of Atlantic (*Urosalpinx cinerea*) and Pacific (*Ocinibrellus inornata*) oyster drills and more recently the worm parasite of cultured abalone, *Terebrasabella heterouncinata,* introduced with shipments of abalone from South Africa (Moore et al. 2007)**.** Other shellfish pests include the predatory flatworm *Psedostylochus ostreophagus* and the parasitic copepod *Mytilicola orientalis*.

Importation of shellfish for aquaculture and sale in California began in 1851 with the first shipment of Olympia oysters (*Ostrea lurida*) from Willapa Bay, WA (then Shoalwater Bay). Shipments of the Eastern oyster *Crassostrea virginica* began arriving in San Francisco Bay as early as 1869 with more than 33,000 bushels per year shipped annually between 1887-1900 (Gordon et al. 2001). Beginning in the 1930s, the Pacific oyster *Crassostrea gigas* from Asia was experimentally planted into bays throughout the state including Newport Bay, Morro Bay, Elkhorn Slough, San Francisco Bay, Drakes Estero, Tomales Bay, and Bodega Harbor (Conte et al. 1994, Shaw 1997). The importation of *C. gigas* as well other non-native oysters including *C. edulis* and *C. sikamea* (=*C. gigas sikamea*, Hedgecock et al. 1999, Camara et al. 2008) continues to this day (Conte 1997, Conte and Moore 2001).

While this is not a complete list of aquaculture introductions, oyster imports represent the most common route for the significant numbers of species introduced during this time. Many other species typically associated with either Eastern or Pacific oysters were also unintentionally introduced as hitchhikers, including many fouling species.

Quantifying the Risk Posed by Aquaculture Introductions

The risk posed to natural resources and society by a non-indigenous species (NIS) is a function of the likelihood that a species will:

- Be introduced
- Establish
- Spread
- Cause 'harm' (Lodge et al. 2006, Williams and Grosholz 2008).

Objectives

The primary objective for this report was to evaluate the relative risk of non-native species spread associated with aquaculture. A risk assessment of the potential threats that non-native species associated with aquaculture pose to California's marine resources ideally would include the probability that a species will be introduced, establish, and spread, and an estimate of the 'harm' it would cause to ecological and economic resources (Lockwood et al. 2009, Ricciardi et al. 2011). Our broad goal was to assess the quality and quantity of available data for each of these steps in the invasion pathway. The probability of introduction, for example, is highly correlated with propagule supply (Lockwood et al. 2005). In aquaculture, propagule supply would be represented, for example, by data on the quantity and identity of aquaculture product(s) delivered to California over time and non-native species associated with these products.

The overall objective of the project was to generate the first comprehensive estimate of the number of species in the aquaculture in California, the proportion of species that have or are likely to become a significant management problem based on documentation of previous invasive history and life history characteristics, and the 'propagule supply', which is the number of individuals circulating in the vector (if data are available). Propagule supply provides first-cut estimate of the importance of this vector for introducing non-indigenous marine species to California. Ideally, it would be important to estimates of propagule size (number of individuals released in a single event) and propagule number (the number of discrete release events), together which compose 'propagule pressure' (as applied in invasion biology literature; Lockwood et al. 2005, Colautti et al. 2006). These data are important but not sufficient for assessing the risk posed by non-indigenous species.

Our specific objectives were to:
1. Characterize aquaculture trade in California, past, current and future;
2. Identify non-native species introduced by aquaculture trade;
3. Characterize taxa introduced by aquaculture trade;
4. Assess statewide rate of introductions via this vector, as well as describe temporal and spatial trends;
5. Assess potential impacts of NIS introduced by aquaculture trade;
6. Evaluate factors likely to affect rate of introductions, establishment and spread.

Conceptual Risk Assessment Model

We develop a single risk model in parallel with the other vectors in this report. There are many conceptual frameworks for assessing the risk imposed by non-indigenous species (e.g., Catford et al. 2009, Blackburn et al. 2011, Gurevitch et al. 2011, Olden et al. 2011, Thomsen 2011a, b). Some favor species distribution modeling to predict occurrence, some take a spatially-explicit, landscape approach, some include management actions, and others focus on propagule pressure or address how the recipient community shapes the success or failure after introduction. With the exception of frameworks that completely ignore impacts, all the frameworks are based on understanding factors that influence the main consecutive steps in the invasion process: delivery of the species, introduction, establishment, spread, and impact.

Starting in 2008, the Ocean Science Trust (OST) initiated a series of workshops involving scientists working on vectors for non-indigenous marine species in California. OST then developed the Aquatic Invasive Species (AIS) Project, which identified three teams each dedicated to a pair of the six vectors, which included aquaculture. The authors of this report collaborated with teams working on other vectors to develop a consensus for the following simple and broad conceptual model as a starting point for a comparative risk assessment of the *vectors*, to guide data collection and assess the availability of data to complete a risk assessment. See Coordination Across Vectors below.

Through consensus building workshops early in the project, the AIS teams agreed upon the following conceptual model for risk assessment to guide data collection:

$$\text{Risk} \propto f\,(P_{\text{introduction}} \times P_{\text{establishment/spread}}) \times P_{\text{Impact}}, \text{ where} \qquad (1)$$

$P_{\text{introduction}}$ is the probability that a vector will introduce a non-indigenous species to California,

$P_{\text{establishment/spread}}$ is the probability species in the vector will establish and possibly spread once introduced, and

P_{Impact} is the probability that species associated with the vector will cause ecological or economic harm to native ecosystems and society.

Risk in this model is specific to an individual vector, as opposed to species. We used this model to guide the data to be collected and analyzed. Given the lack of information on many of the vectors including aquaculture and specifically for California, $P_{\text{introduction}}$ was addressed in the simplest, first-cut way as the flux of individuals in the vector as they are delivered over time. $P_{\text{establishment/spread}}$ can be estimated most simply as the proportion of species that successfully establish of those that are introduced. The probability of impact is the term in the model that has been most challenging to define because 1) impact data are species-specific, and 2) many of the non-indigenous marine species introduced to California cannot be ascribed to a single vector like aquaculture. Data sources for impacts can be found in published studies, but a numeric scoring of an impact must be made before such impacts could be incorporated into a more formal semi-quantitative risk assessment or an expert opinion solicitation must be performed for the vectors (see Risk Assessment in Ornamental Trade Vector Report).

The specific elements of this report follow those from the original contract, however these were modified where needed due to the lack of availability data. We completed the following elements:

1) Complete listing of non-native species associated with the aquaculture vector
2) Sites and dates of first introduction and relative rates of introduction from for different source regions
3) Spatial and temporal variation in patterns of introductions
4) Introduction rates vs. establishment success

5) The role of aquaculture in the primary and and secondary dispersal
6) Impacts of selected taxa introduced by aquaculture based on a review of scientific literature
7) Past, current and potential future trends based on current information about risks posed by current and potential future industry practices
8) Control points and strategies and options for management

2.0 Methods

Aquaculture trade in California, Past, Current and Future

We used several approaches to characterize non-native species used in California aquaculture, from past to present. Our main approaches were to obtain data on species, propagule supply, and spatial and temporal trends from state and federal agencies with permitting and regulatory authority over aquaculture or importations of non-native species designated for aquaculture in California. We documented the contacts we made as we explored agency sources of data. We identified the types of permits required for aquaculture (listed below) and reviewed such permits. Additionally, we discussed with department staff the current and historical use of the different types of permits, along with reading relevant agency literature and written regulations.

To our knowledge, there is no single agency to which all commercial aquaculture companies report the type, number and source of organisms that are being imported into the state or the fate of these organisms. Both managers and growers face the challenge of determining the types of permits required, the specificity required by each permit, and the repository for the permits. Several state and federal agencies require permits with the primary agencies being California Department of Fish and Game (CDFG), US Fish and Wildlife Service (USFWS) and the US Army Corp of Engineers (USACE) (Fig. 1a,b). Multiple agencies are involved in regulating importation of live organisms from outside the US and from outside California, and regulations and permits vary depending on type of organism and the purpose of the import. Aquaculture facilities in the state must obtain permits from CDFG, California Department of Public Health, and from the US Army Corps of Engineers if they intend to place organisms and/or structures in state waters, but few details are available about the volume and frequency of actual plantings. Additionally, all commercial aquaculture facilities selling shellfish for human consumption must prepare and file a management plan with the California Department of Public Health. Figures 1a and 1b summarize the permits and regulatory agencies involved in the movement and placement, respectively, of aquaculture species.

2.1 California Department of Fish & Game (CDFG) Aquaculture Permits

The California Department of Fish and Game (CDFG) regulates the transfer across state borders of animals to be placed in state waters through its import permit process (Fig.1a). CDFG also manages 'State Water Bottom Leases' in several estuaries and bays and leaseholders must fill out additional permits and statements, including information on their yearly plantings and harvesting with species and volume (Fig. 1b). Import and aquaculture permits, bottom lease records, and associated paperwork are on file at CDFG, and we used these to characterize aspects of the aquaculture industry.

We reviewed records pertaining to importation of aquaculture species and aquaculture leases at the CDFG office in Eureka. CDFG staff has many of the recent aquaculture permitting records entered into department databases and/or these records are well organized as paper permits in filing cabinets. Older files were disorganized and stored in boxes. We inventoried the files in these boxes and entered some of these records into various databases to extend the historical perspective of aquaculture in California (see Table 1 in Results for the various databases and types of data collected).

Specifically, we sought records and information on:

1. Which species have been/are being brought into the state (and transferred between bays) for aquaculture purposes

2. Volume (i.e., number of individuals, pounds, bushels, etc.) of such species over time, to estimate propagule supply

3. Origin of such individuals (i.e., where individuals are being brought from as opposed to their original native range)

4. Locations where aquaculture species have been/are being placed and the extent (size) of these operations

5. Past and current regulations and controls in place to prevent the spread of non-native species via this vector

2.2 United States Army Corps of Engineers (USACE)

Since 1890, aquaculture businesses placing structures that change the flow of water and/or affect the substrate in state or federal waters have been required to obtain federal permits (Fig. 1b). To estimate historic and current acreage in aquaculture, we filed a Freedom of Information Act request with the San Francisco and Los Angeles offices of USACE. Records have not been kept in a manner that allowed for retrieval of aquaculture-specific permits in a timely fashion at the San Francisco office. We were able to visit the LA office to review archived aquaculture-related records.

2.3 United States Fish and Wildlife Service (USFWS)

The United States Fish and Wildlife Service (USFWS) must inspect invertebrate species imported into California from outside the United States (Fig. 1a). However, from 1989 to the present, very few foreign imports have occurred for invertebrate species for aquaculture purposes. Additionally, from 2003 to the present, no permits have been filed with CDFG for foreign imports of invertebrate species for aquaculture purposes. Therefore, very little data on aquaculture is to be gained from USFWS, and we do not report any results from this agency in this report.

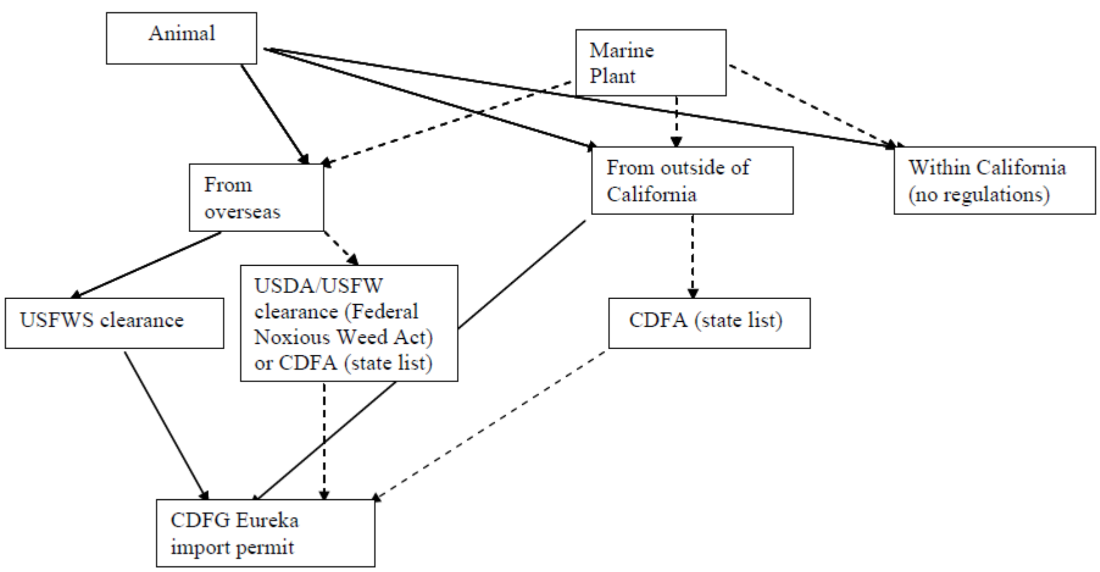

Figure 1a. Flow chart of permits, inspections and regulating agencies for the movement of aquaculture species into and within California. Solid lines indicate the pathways for animal imports, dashed lines for plant imports.

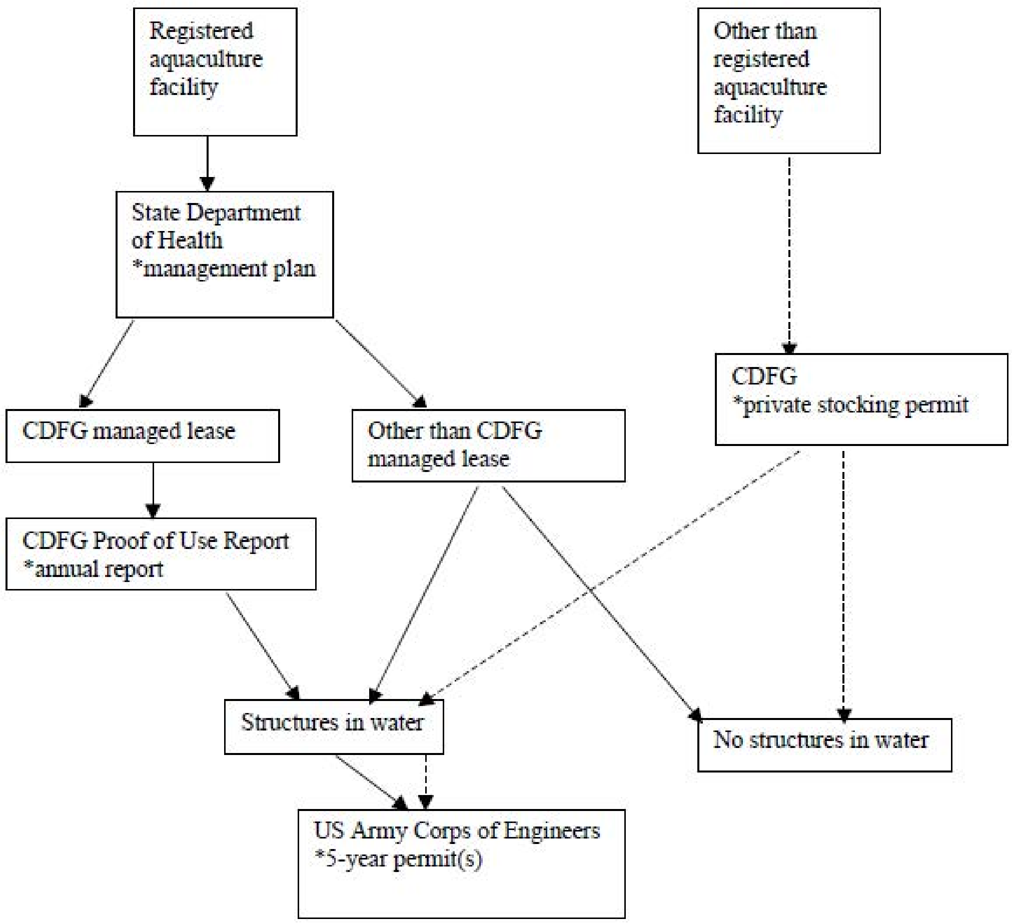

Figure 1b. Flow chart of permits and regulating agencies at the state and Federal levels for aquaculture facilities that we used to obtain information on the extent and distribution of state's aquaculture industry. Asterisks indicate required forms, permits and reports. Solid lines indicate regulations for commercial facilities; dashed line indicates regulations for non-commercial facilities. Additional permits are required for environmental, planning and other purposes, but do not regulate the aquaculture organisms per se, and are distributed among many local jurisdictions.

2.4 Temporal and spatial trends in introductions

To characterize temporal and spatial trends in introductions related to aquaculture, we extracted a list from the NEMESIS database of established non-native species likely to have been introduced to California by the aquaculture trade (http://invasions.si.edu/nemesis/index.html). NEMESIS is a project of the Smithsonian Environmental Research Center (SERC) and was compiled from peer-reviewed scientific literature and the gray literature starting as early as 1853 through the present. A subset of the NEMESIS data, species introduced to California (CA NEMESIS) was comprehensively reviewed by SERC. Species were added to CA NEMESIS through 2011. CA NEMESIS includes species known to be non-native, those thought to have established populations, as well as species that have failed to establish or have gone extinct since becoming established. Species whose non-native status is uncertain, defined as "cryptogenic", are not included.

SERC researchers assigned species to vectors based on a thorough review of the literature, basing these decisions on a number of factors including any direct links to vectors, species' life history characteristics and history of vector operation in specific locations (for example, ballast water might be excluded as a potential vector from a water body that cannot accommodate large commercial vessels, or in cases where a species was reported from a location before ballast water was used in commercial shipping). In some cases, species were assigned a single vector, however, in most cases several vectors were possibly and/or likely. These species where more than vector is possible or likely will be referred to below as 'polyvectic'. We conducted our analyses using both the conservative list (aquaculture as sole vector) and the expanded list (aquaculture as one possible or likely vector). Species associated with aquaculture include those intentionally or unintentionally transferred as part of an official or unofficial aquaculture operation (generally Eastern or Japanese oysters, but including some clam species) or as part of an official or unofficial stocking operation, intended to establish populations for food.

We cross-referenced the NEMESIS list against two other sources: 1) a database complied for the Coastal Environmental Quality Initiative (CEQI) project, a literature review that included reports of non-native and cryptogenic species from estuaries and bays within California, (Williams and Grosholz, unpublished data) and 2) a database of non-native algae literature review from 1995 through 2006 compiled by Williams and Smith (2007). We updated the algal database with a search of the literature from 2006 through 2011.

We modified the NEMESIS database slightly regarding species listed for the aquaculture vector (also see Ornamental Trade Vector Report). We removed species that were obligate (or nearly so) freshwater species based on available literature and reclassified species erroneously listed as intentional if they were parasites or associated fouling species that were most likely 'unintentional' introductions associated with intentional fish or oyster introductions (see Appendix I). Additionally, we updated some species names and higher taxonomic classifications.

Because actual dates of introduction and/or establishment are generally unknown, we used the year of the first report for the state as a proxy for year of introduction to the state. In reality, in nearly all cases species were first introduced some unknown time before they were first reported in the literature.

We examined temporal trends for first reports on both a statewide (reported from anywhere in California) and a bay wide (reported from a specific bay or water body) basis. We examined the data to determine the spatial extent of aquaculture-associated NIS across bays or other water bodies.

Because of the uniformity of industry practices since approximately 2000 onward, we compare the numbers of species introduced unintentionally via aquaculture prior to 2000, henceforth referred to as "hitchhikers", with the numbers of hitchhikers brought into CA after 2000. This will allow us to better assess the current and future risks of invasion via aquaculture using 2000 as the time point after which the potential risk of invasion by associated species or "hitch hikers" should be greatly reduced.

2.5 Impacts of NIS introduced by aquaculture trade

Using the NEMESIS list of non-native algae and mollusc species introduced to California, we searched the peer-reviewed scientific literature and created a database of studies on the impacts of mollusc and macroalgal species. A similar database was created by the SERC group for crustaceans and is displayed in the SERC reports on boating vectors. These three broad taxonomic groups make up a significant portion (>60%) of the non-native species in California. Both groups conducted the searches from November 2011 to March 2012 for all taxa. The time span for the BIOSIS search was 1926 to the end year of 2011.

All searches were completed with the following search terms in BIOSIS:
Topic=(Adventive OR Alien OR Bioinvasi* OR Biosecur* OR Exotic* OR Foreign OR Introduc* OR Incursion* OR Invad* OR Invasi* OR Non endemic* OR Nonendemic* OR Non indigenous OR Nonindigenous OR Non native* OR Nonnative* OR Nuisance* OR Pest* OR Pest) AND Topic=(species name in quotes, e.g. "Sargassum muticum") AND Timespan=1926-2011.*

Searches were also carried out using synonyms for the current species name. We used WoRMS (World Registry of Marine Species) for lists of synonyms. We performed an initial sort by reading through the returned titles (>95% of papers for most species were not relevant). We sorted secondarily by reviewing abstracts and obtaining articles. Data from the relevant impact studies were extracted and entered into the impact spreadsheet. For each study, the following data were extracted: authors, year of publication, introduced species name, vector and species origin if listed in article (for comparison, not actually used to attribute vector), recipient habitat type (e.g. bay, intertidal, etc.) and location, impacted entity, name, metric, and category, direction of effect listed, study type and setting, statistical analysis, the presence of reported mean effect size, and if there was an error term for the mean effect size reported. The study types were categorized as observational (lacking statistical analysis, limited comparisons, models, calculations), mensurative, or experimental (Williams 2007, Williams and Smith 2007). Mensurative and experimental studies included a replicated statistical design; experimental studies involved manipulations of native organisms and/or the non-indigenous species. Only mensurative and experimental studies were included in the impact analyses. A case as used in statistical meta-analyses is defined as a single result or effect for a single response variable; thus, an experiment or study or publication can include multiple cases

3.0 Results

Key Finding *– Currently, no centralized database exists for either species associated with aquaculture or marine invasive species in California. There are multiple permit processes, multiple independent and uncoordinated databases and several agencies with overlapping authorities that prevent a comprehensive assessment of aquaculture as a vector for non-indigenous species introductions.*

Detailed data on the state's aquaculture industry were difficult to obtain. There is no central permitting agency that keeps records of all of the data we were seeking. The data gathered from CDFG and USACE were inadequate to estimate the identity or volume of aquaculture species imported into the state or to reveal detailed temporal and spatial trends for aquaculture in California. This is in part due to the fact that state agencies do not require follow up reporting from permit-holders. For example, CDFG does not require importers to report the actual importations made post-permit approval. Through the federal agency USACE, all aquaculture facilities should be under permit, however, compliance is low and there is no accurate record of historical aquaculture acreage.

We present the results from working with actual permits obtained at state and federal offices as well as online data resources where available.

3.1 California Department of Fish and Game Aquaculture-Related Permits

Table 1 summarizes the types of aquaculture permits in use or formerly used by CDFG, the years for which these records exist, the type of information reported on each permit, and the status of the availability for records on file. See Appendix II and III for examples of the current and historical permits used for transferring live invertebrates from out of California into state waters.

3.1.1 Aquaculture Facility Registration

All California aquaculture facilities must register yearly with California Department of Fish and Game. See Appendix IV for example of the FG 750 'Aquaculture Registration Application'. This registration requires reporting the name and address of aquaculture business, general location of facilities, and general species cultured.

Currently, approximately 6040 acres of aquaculture water bottom lease area are registered with CDFG. These acreage values represent the maximum possible aquaculture acreage within the state of California. Some of this acreage may be unused due to expired leases or companies going out of business. Additionally, many aquaculture facilities use only a small subset of possible acreage for growing (e.g. Humboldt Bay has 3913 acres, however, only about 400 acres currently support aquaculture).

Of the total acreage, CDFG manages about 1952 acres (32.3%); other entities manage the remaining 4088 acres (67.7%). CDFG has leases in Tomales Bay, Drakes Estero, and Morro Bay, along with some in Santa Barbara County. Non-CDFG held leases exist in Humboldt Bay, Monterey Bay, Santa Barbara county, and San Diego county. These leases are held and regulated by other local entities (e.g. City of Santa Barbara) and have minimal mandatory reporting to CDFG. The water bottom leases held by CDFG have changed from the 1960s to today. See Table 2 for a list of lease acreage and owners.

Table 1. Permits kept by the California Department of Fish and Game (Eureka, CA) relevant to the state's aquaculture industry.

Data type	Information covers	Time period for which records were available	Data fields
Import permits	State	1989 to June 2011, records mostly complete	Importer, exporter, species, some volume
Proof of Use Reports	For leases managed by CDFG	Records incomplete, 1977-2010	Importer, exporter, species, dates, volume
Inspection and planting certificates	State	Records incomplete, 1964 – 1983	Species, dates, volume
Private stocking permits	State	1992-2009	Importer, exporter, species, dates, volume

Table 2. Aquaculture acreage by bay and water bottom lease managing entity. Acreage refers to total acreage leased and not acreage under active aquaculture.

California Bay	Lease Manager	Acreage
Humboldt Bay	Humboldt Harbor Resource & Conservation District	3913
Tomales, Drakes Estero, Morro, & Santa Barbara	CDFG	1952
Santa Barbara	City of Santa Barbara	168
San Diego (Agua Hedionda Lagoon)	NRG Energy Inc.	5
Monterey	Other? N/A?	2

3.1.2 Import Permits

Key Findings - *The number of import permits issued annually has not changed significantly from 1989 to mid-2011 despite significant annual variation. This suggests that the risk of introduction that is associated with import shipments has not declined. However industry practices discussed below have substantially reduced invasion risk of hitchhiker species. The vast majority of permits were for oyster subspecies and one clam species: Crassostrea gigas, C. gigas sikamea, and Venerupus philippinarum.*

- Aquaculture efforts have varied considerably across bays in the state. The volume, number of species, and species composition of aquaculture imports differs markedly across bays. Source locations for imports also vary, with some bays receiving stock from multiple regions and others having few. Source locations have also shifted over time.

Import permits are required for marine fish being imported into the state for human consumption and for marine species destined for placement in state waters (generally for aquaculture or research purposes). No permits are required for movement of live marine organisms within the state. CDFG issues two types of import permits, standard (Form FG 789 'Standard Importation Permit') and long-term (Form FG 786 'Long-Term Permit', see Appendix II). The standard permit is for a single import of a specified volume and species from one source supplier. The long-term is for a specified species to be imported via multiple shipments from one source supplier with no specified volume. Long-term permits expire after one year from date of issuance. Both types of permits were used in the late 1980s to early 1990s. However, from the mid-1990s to the present, CDFG switched to mainly using the long-term permit even for one-time use if the organisms to be imported are a common aquaculture species imported from a well-known commercial supplier.

Permits for the years 1989 through 2011 are on file at CDFG in the Eureka office and all recent import records (2004 to 2011) are in an electronic database. We reviewed the paper files and added import records for the earlier years (1989 to 2003) to this database for those records related to aquaculture activities. Additionally, we added columns to the database for import destinations, use, volume, and whether conditional letters were attached (1998 to 2011). We provided CDFG a copy of the amended database.

A total of 328 standard and long-term import permits for aquaculture related activities were issued between 1989 and 2011. The permits do not indicate which species or how many of each were actually imported or planted, but can provide a relative indication of activity over time and region. To determine this, we calculated the number of permits for a given species per year for the years 1989-2011 (the time for which import permits were available). Some companies applied for multiple species in a single permit and others applied for multiple single-species permits, therefore we calculated the number of permits for each species to generate these data; hereafter a permit refers to each individual species permitted.

The Pacific oyster, *Crassostrea gigas,* represents the single greatest number of permits issued since 1989. Imports of *C. gigas* account for slightly less than half (43%) of all aquaculture import permits issued by CDFG over this time period (Fig. 2). *Venerupus philippinarum* (21%) and *Crassostrea sikamea* (17%) are the second and third highest taxa for which import permits were issued. These three taxa represent a combined 81% of the import permits issued from 1989 to June 2011. However, in the early and mid-1990s these three species represented a smaller proportion of the species imported (Fig. 3). From 1989 to 2011, species imported for aquaculture have become less diverse, but the number of permits issued annually has been relatively unchanged over this period of time despite significant annual variation. We tested this using the import permit data in Fig. 3 to determine if there was a significant difference in the number of import permits per year before vs. after 2000. We found no significant difference in the number of import permits prior vs. post 2000 (t-test; $t_{21} = -2.07$, $p>0.05$) suggesting that the quantity of imports in CA has not declined.

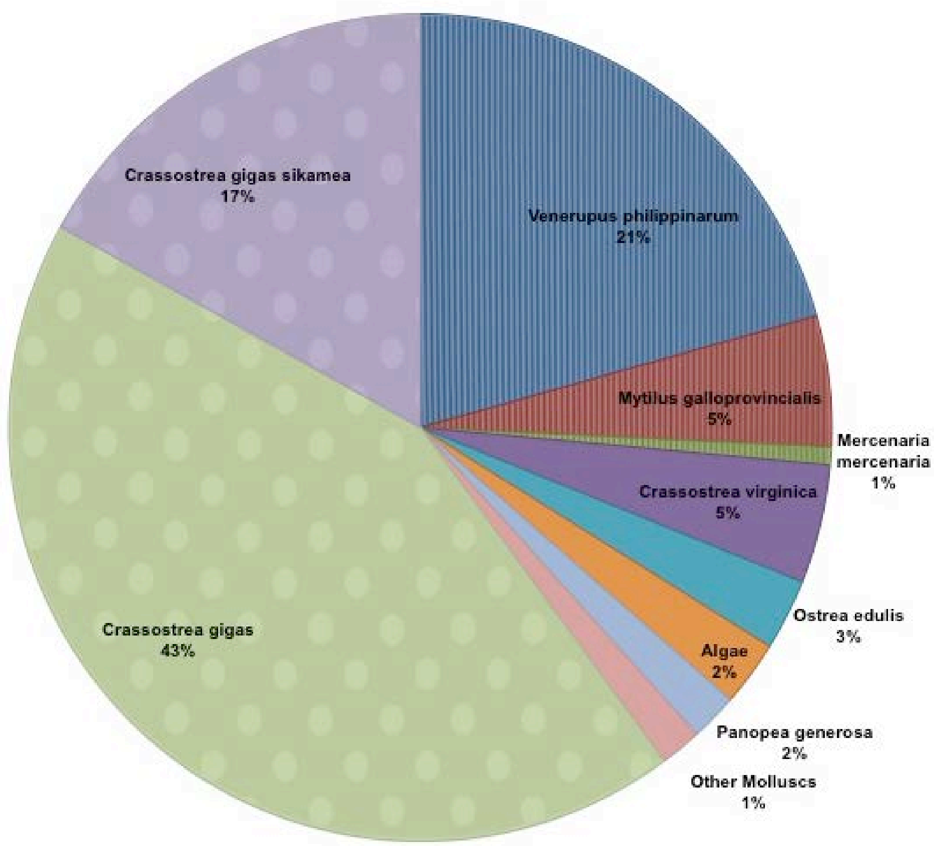

Figure 2. Number of species specified on import permits for 1989 to 2011. *Haliotis rufescens, H. discus hannai, Patinopectin caurinus, Ruditapes decussatus, Crassodoma gigantea* and *Crassostrea rivularis* make up 1.6% of the total imports and are labeled as, 'Other Molluscs,' 'Algae' refer to two species, *Nereocystis luetkeana* and *Palmaria mollis* and make up 2.5% of the total imports. Striped lines on chart denote non-native species that have become established in California, and dotted areas denote non-native species that have been introduced to California (reported from non-aquaculture

environments), with current status unknown, according to NEMESIS. Data source: California Department of Fish and Game.

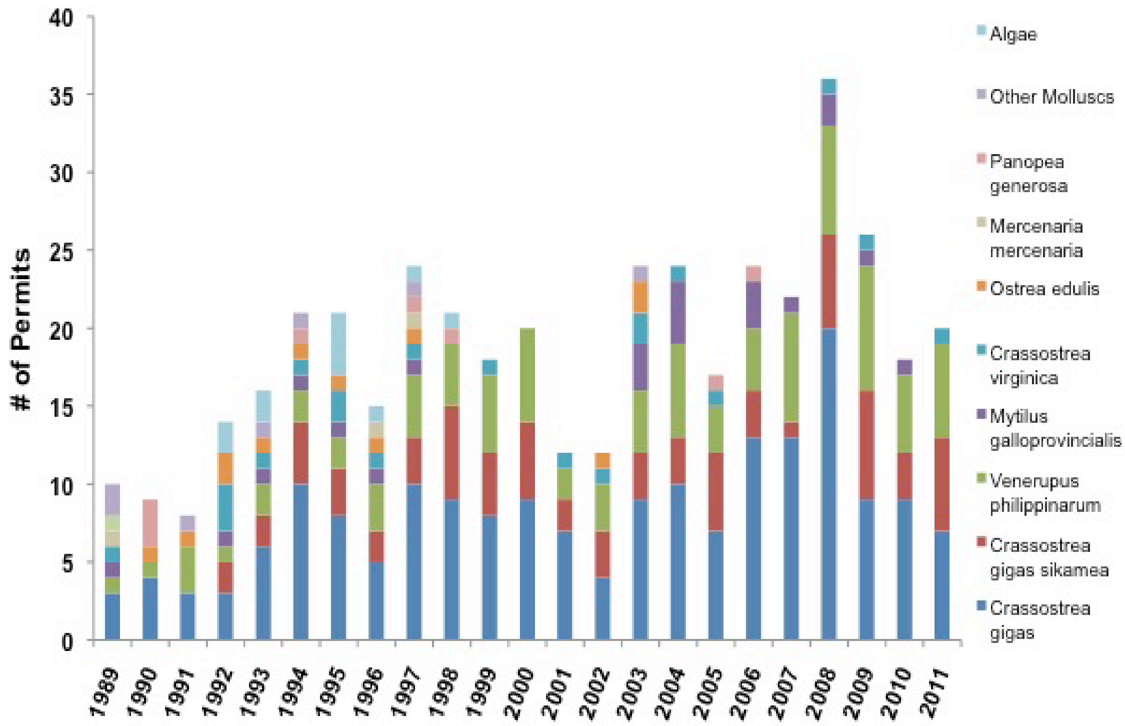

Figure 3. The number of import permits per year from 1989 to 2011. *Haliotis rufescens, H. discus hannai, Patinopectin caurinus, Ruditapes decussatus, Crassodoma gigantea* and *Crassostrea rivularis* are combined and labeled as, 'Other Molluscs,' 'Algae' refer to two species, *Nereocystis luetkeana* and *Palmaria mollis*. Data source: California Department of Fish and Game.

Aquaculture species have not been evenly distributed geographically within the state (Fig. 4). While Humboldt and Tomales are nearly identical in terms of the species and proportions of species used in aquaculture, raising mainly *C. gigas, C. sikamea,* and *V. philippinarum,* these three species represent only about half of Morro Bay's and 30% of Santa Barbara's permits. The seaweed *Palmaria mollis* forms a higher proportion of the permits for aquaculture species in both of these Central California locations, as does the mussel *Mytilus galloprovincialis. M. galloprovincialis* also represents a large proportion of the aquaculture in San Diego, along with *V. philippinarum.*

For nearly every year for which we have data, the greatest number of permits issued was for companies based in Humboldt Bay, with Tomales Bay as a close second (Fig. 5). In total (1989 to 2011), Humboldt and Tomales Bays are the destinations specified on 52%

and 33% of the aquaculture-related import permits, respectively. With very few exceptions, all other bays consistently had five or fewer permits issued per year.

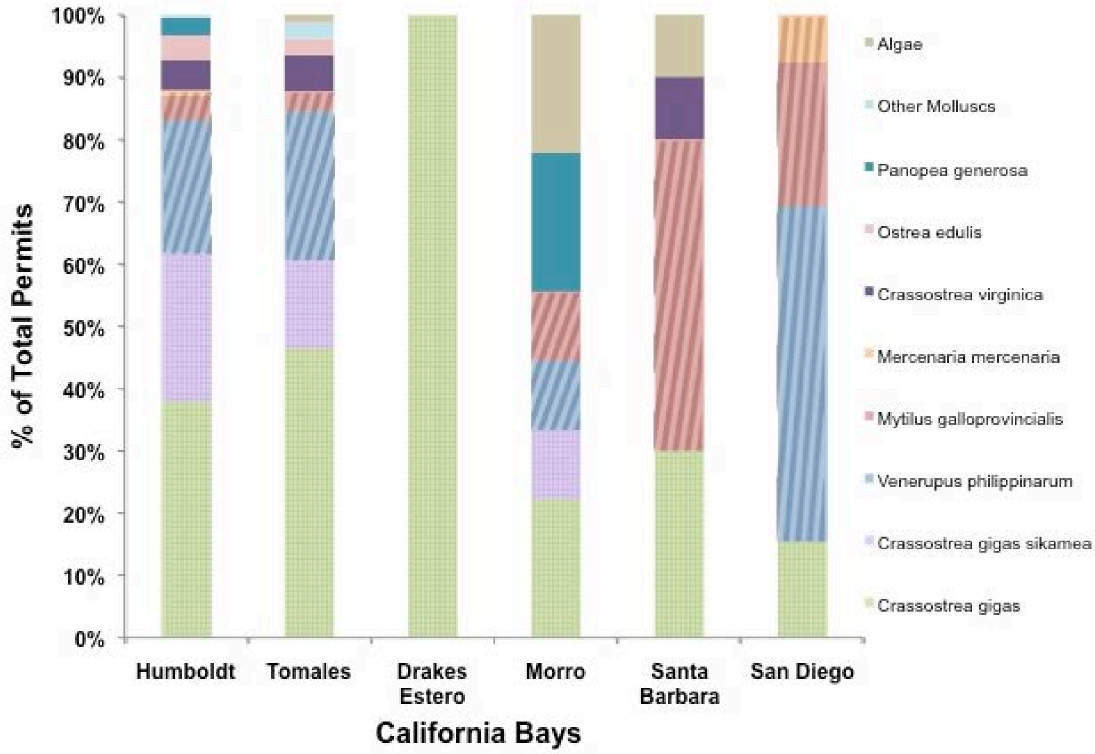

Figure 4. Percent of species by geographic destination, all years (1989-2011) combined. *Haliotis rufescens, H. discus hannai, Patinopectin caurinus, Ruditapes decussatus, Crassodoma gigantea* and *Crassostrea rivularis* are combined and labeled as, 'Other Molluscs,' 'Algae' refer to two species, *Nereocystis luetkeana* and *Palmaria mollis*. Striped lines on chart denote non-native species that have become established in California and dotted areas denote non-native species that have been introduced to California (reported from non-aquaculture environments), with current status unknown according to NEMESIS. Data source: California Department of Fish and Game.

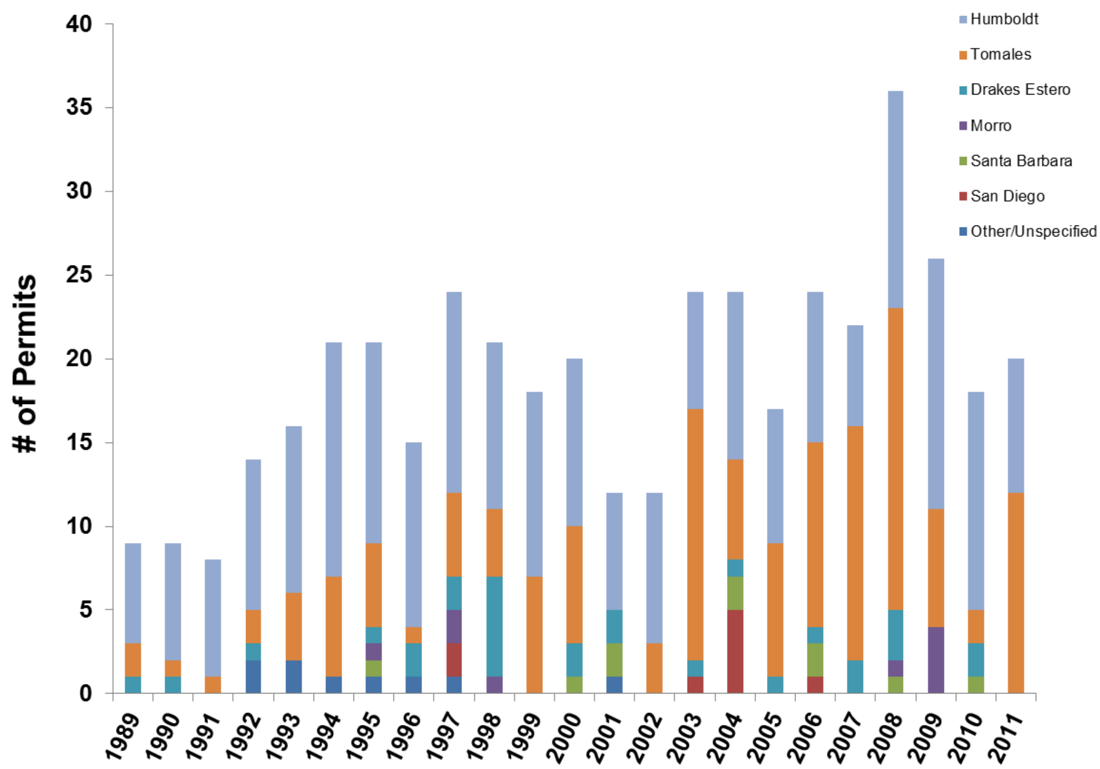

Figure 5. Number of import permits by year and destination. Data source: California Department of Fish and Game.

The majority of aquaculture imports (1989 – 2011) to California are from Washington state (56%); over this time period, a combined 80% of imports come from Washington and Oregon (Fig. 6). However, the geographic source for aquaculture stock has shifted over time. While Washington has been a major source over the years for which we have data, the proportion coming from Hawaii has increased greatly over the last four years. Imports from Hawaiian sources represent 15% of the total permits issued between 1989 to 2011. Imports from Mexico began in 1996 and continued through 2003, but Mexican exporters have not supplied animals to California since then. The East Coast of the United States was an important source for the very early years of aquaculture in California (Gordon et al. 2001), but imports from Maine appear in only two years -- 1992 and 1995 -- in this more recent data set. Imports have also come from Japan in 1989 and 1997, Australia in 1994, and Canada (British Columbia) in 1991 and 1997.

Source locations are different for the various bays in which aquaculture companies are located (Fig. 7). For example, for the years 1989-2011, San Diego appears to have imported only species from Washington, while Santa Barbara and Morro Bay solely imported from Washington and Oregon. Humboldt, Tomales, and Drakes Estero have received most of their shipments from Hawaii, Oregon, and Washington. Hawaii is a source of aquaculture imports only for northern California bays. During this time period, northern bays (Humboldt, Tomales, Drakes Estero) have had more import sources than bays south of and including Morro. Tomales Bay has the most diverse set of sources, including Australia, Maine and Alaska; Humboldt has received imports from Canada, and Drake's Bay from Japan and Mexico.

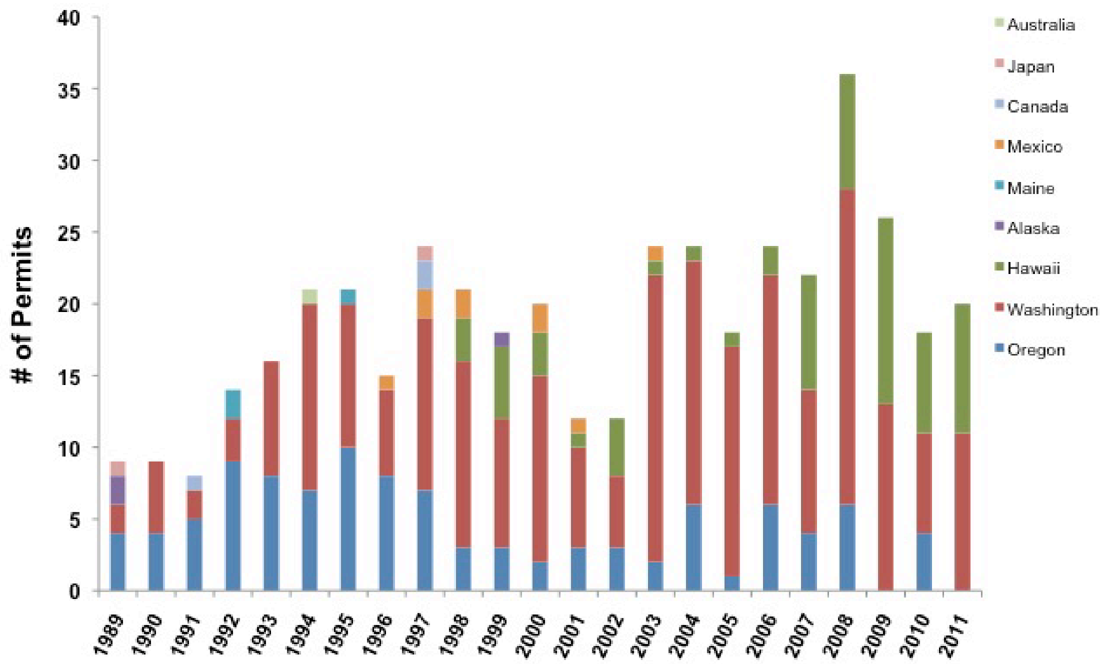

Figure 6. Origins of aquaculture species imported to California by year. Data source: California Department of Fish and Game.

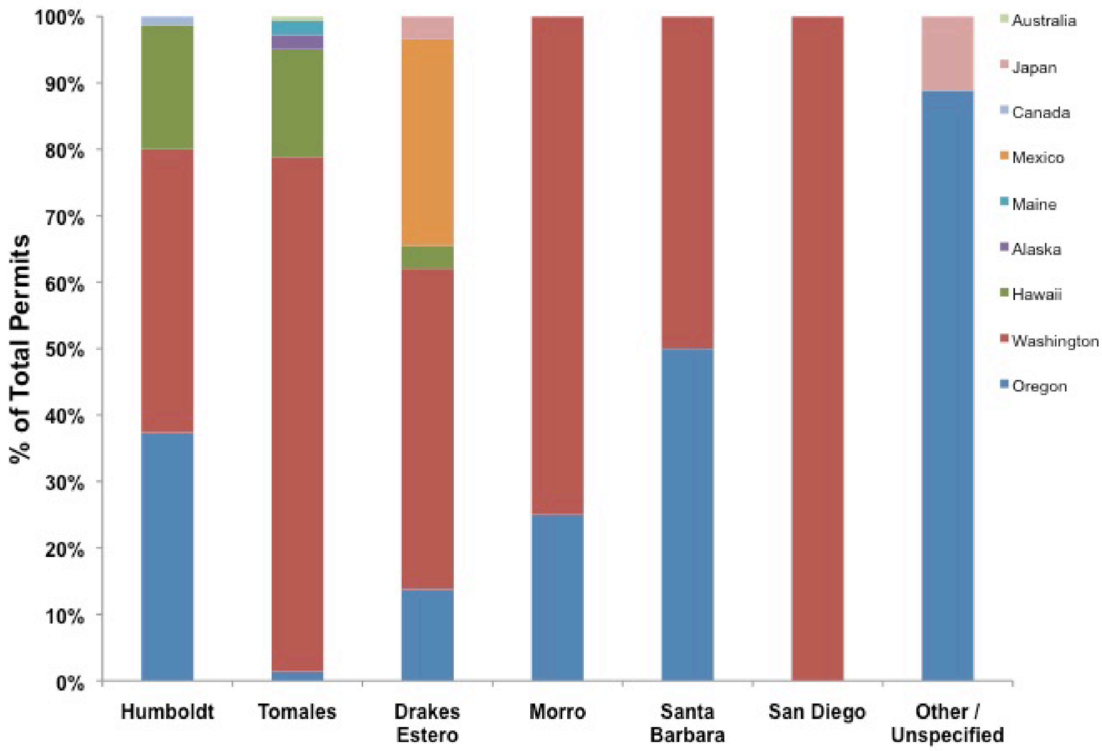

Figure 7. Origins of aquaculture species imported to California by geographic destination, as permit-species for the years 1989 to 2011. Data source: California Department of Fish and Game.

3.1.3 Private Stocking Permits

Key Finding – *Private stocking permits, issued primarily for restoration of native species, have also been granted for the placement of large numbers of non-native species in state waters. Used when an applicant does not represent a registered aquaculture facility, these permits are relatively rare, but represent another avenue for the introduction of non-native species.*

Private stocking permits (Form FG 749 'Application for Private Stocking Permit') are issued when individuals intend to place live aquatic plants or animals in state waters in locations other than a registered aquaculture facility. Such permits are required whether the organisms are imported into the state or are being transferred within the state, and a standard or long-term import permit must also be obtained in the former case. Private stocking permits are primarily used to stock fish in freshwater lakes and are rarely used in the marine environment. According to the CDFG, the most common marine purpose for which a private stocking permit would be appropriate is for restoration, however these activities may be permitted with a letter instead. CDFG's Eureka office has recorded private stocking permits for the years 1992-2009 in a database. There are 38 records related to the marine environment for this time period. While many of the species planted under private stocking permits are native to California, both *C. gigas* and *M. galloprovincialis* have also been permitted, showing that these types of plantings represent potential vectors for the movement of non-indigenous species (Table 3).

Box 1. Private Stocking Permits. Private stocking permits are used in place of import permits when animals are to be placed in state waters by a person or agency that is not a registered commercial aquaculture facility. The most common purpose for such permits is for research and restoration and many are for species native to California, such as the Olympia oyster *Ostrea lurida*. However, over the past two decades, non-native species, including Pacific oysters, *Crassotrea gigas,* sometimes in large amounts, have been permitted through private stocking permits including 5000-7000 to one agency on Catalina Island in 2006 and up to 10 million to individuals in Tomales Bay in 2007 and 2008.

Table 3. Species placed in California waters outside registered facilities through private stocking permits. Non-native species are in bold. In cases where species were identified only as "abalone," "clams" or "oysters" we could not make such a determination.

Species	Common name
Abalone	
Clams	
Crassostrea gigas	**Pacific oyster**
Haliotis corrugata	pink abalone
Haliotis fulgens	green abalone
Haliotis rufescens	red abalone
Megathura crenulata	giant keyhole limpet
Mytilus californianus	California mussel
Mytilus galloprovincialis	**Mediterranean mussel**
Mytilus trossulus	bay mussel
Ostrea lurida	Olympia (native) oyster
Oysters	
Paralichthys californicus	California halibut
Stronglyocentrotus francisanus	Red sea urchin

3.1.4 Inspection and Planting Certificates

Key finding *– Sources for the state's aquaculture were significantly more varied in the '60s-80s and included the transfer of adult animals from East Coast and foreign locations. Records are highly fragmentary and thus represent only a snapshot of the diversity of target species and source locations.*

Prior to the mid-1980s, CDFG required Inspection and Planting Certificates for all commercial and personal aquaculture related activities within state waters. These certificates included species names, volume, source, destination and use, and were signed by a shellfish health inspector. These inspection and planting certificates were for both transfers of organisms from out of state and within state waters. We entered all Inspection and Planting records into a database for the years for which we could find records, 1964 to 1983. During this time period, sources included the US East Coast (Massachusetts, Maine, Rhode Island, New York), US West Coast (Washington, California, Oregon), and international locations (Japan, British Columbia) (Table 4). These permits were discontinued in the mid-1980s. At this time, private Stocking Permits for personal-use aquaculture and Proof of Use statements (below), which begun to be used a few years earlier for commercial aquaculture facilities on CDFG managed leases, replaced these permits. Reporting of within state water shellfish transfer was discontinued and the import permits were implemented for all out of state transfer of aquaculture species to state waters.

Records from before 1989 are fragmentary, but some Inspection and Planting Certificates indicate that transfers of aquaculture species from the East Coast and Japan were more frequent in earlier decades. Transfers also occurred frequently between estuaries and/or aquaculture facilities within the state. It is not clear whether these aquaculture facilities exchanged water with the bays in which they were resident.

Table 4. **Aquaculture taxa and their sources by year for each destination bay. Data from Inspection and Planting Certificates held by CDFG. Many of the California sources are from hatcheries at these locations.**

Destination	Year	Species	Sources
Drakes Estero	1979	*C. gigas*	Dabob Bay, WA
	1980	*C. gigas*	Pescadero, Tomales Bay, CA; Dabob Bay, Willapa Bay, WA
Elkhorn Slough	1976	*O. edulis*	Moss Landing, Pescadero, CA; South Bristol, ME; Sendai, Miyagi Pref., Japan
	1977	*C. magister*	Eureka, CA
		M. mercenaria	N/A
		M. arenaria	West Sayville, NY
		O. edulis	Moss Landing, Pescadero, CA
		P. interruptus	N/A
		V. philippinarum	N/A
	1978	*C. gigas*	Moss Landing, Pescadero, CA; Newport Bay, OR
		C. virginica	Pescadero, CA
		C. magister	Tomales Bay, CA
		M. mercenaria	Long Island, West Sayville, NY
		M. arenaria	Plymouth, MA
		O. edulis	Moss Landing, Pescadero, Tomales Bay, CA
		O. lurida	Pescadero, CA
		P. interruptus	Santa Barbara, CA

		V. philippinarum	Ocean Park, WA
	1979	*C. gigas*	Tomales Bay, Pescadero, CA; Newport Bay, OR
		C. magister	Half Moon Bay, CA
		M. mercenaria	Long Island, NY; Plymouth, MA; Bar Harbor, ME
		M. arenaria	Long Island, NY; Plymouth, MA
		O. edulis	Pescadero, CA; South Bristol, ME
		Pacific flat oyster	Santa Barbara, CA
		P. interruptus	Santa Barbara, CA
		V. philippinarum	Ocean Park, WA; Vancouver, BC
	1980	*C. virginica*	N/A
	1981	*M. mercenaria*	West Sayville, NY
Humboldt Bay	1964	*C. gigas*	Shiogami, Japan
	1965	*C. gigas*	South Bend, Hoods Canal ,Willapa Bay, WA
		M. mercenaria	West Sayville, NY
	1966	*C. gigas*	Pendrell Sound, BC
	1969	*C. gigas*	Dabob Bay, WA; Miyagi, Hiroshima prefectures, Japan
	1977	*C. gigas*	Willapa Bay, WA
	1978	*O. edulis*	Walpole, ME
Monterey	1978	*H. rufescens*	Santa Barbara, CA
Morro Bay	1978	*C. gigas*	Pendrell Sound, BC
	1980	*C. gigas*	Pendrell Sound, BC
	1981	*C. gigas*	Pendrell Sound, BC
Pigeon Point	1978	*C. gigas*	Yaquina Bay, OR
Santa Barbara	1978	*H. rufescens*	Monterey, CA
San Francisco Bay	1977	*M. edulis*	Tomales Bay, CA
	1980	*C. gigas*	Drakes Estero
		C. virginica	Long Island, NY
	1981	*C. gigas, O. edulis, C. virginica*	Long Island, NY; Tomales Bay, Elkhorn Slough, CA
		M. mercenaria	Dennis, MA
	1981	*M. edulis*	Moss Landing via NY; Tomales Bay, Elkhorn Slough, CA; Narragansett Bay, RI
Tomales Bay	1976	*C. gigas*	Moss Landing, CA; Sendai, Miyagi Prefecture, Japan
		C. virginica	Greenport, NY
	1977	*C. gigas*	Moss Landing, Pescadero, CA; Bellingham, WA; Sendai, Miyagi Prefecture, Japan
		C. virginica	Pescadero, CA; Greenport, NY
		M. mercenaria	Bellingham, WA; Vancouver, BC
		M. arenaria	Plymouth, MA
		O. edulis	Moss Landing, Pescadero, CA
		P. interruptus	Moss Landing, Santa Barbara, CA
		"Pacific clams"	Moss Landing, CA
	1978	*C. gigas*	Moss Landing, Elkhorn Slough, CA; Dabob Bay, WA
		O. edulis	Moss Landing, Elkhorn Slough, CA
	1979	*C. gigas*	Elkhorn Slough, Pescadero, Moss Landing, CA; Dabob Bay, WA

		Bay mussels	Medomak, ME
		O. edulis	Moss Landing, Elkhorn Slough, CA
		V. philippinarum	Elkhorn Slough, CA
	1980	*C. gigas*	Elkhorn Slough, Moss Landing, Pescadero, Drakes Bay, CA; Ocean Park, WA
		M. mercenaria	West Sayville, NY; Martha's Vineyard, MA
		M. arenaria	West Sayville, NY; Martha's Vineyard, MA
		O. edulis	Elkhorn Slough, Pescadero, Humboldt, CA
	1981	*C. gigas*	Elkhorn Slough, Moss Landing, Pescadero, San Francisco, Humboldt, CA
		C. virginica	Moss Landing, San Francisco, CA
		"French oysters"	San Francisco, CA
		Bay mussels	San Francisco, CA
		O. edulis	Elkhorn Slough, Moss Landing, San Francisco, CA
	1982	*C. gigas*	Pescadero, San Francisco, Drakes Bay, Humboldt, CA
		C. virginica	San Francisco, CA; Round Pond, ME
		M. mercenaria	Round Pond, ME
		O. edulis	Elkhorn Slough, San Francisco, CA; Round Pound, ME

3.1.5 Proof of Use Reports

Key finding *– Proof of Use reports represent the only source of data on species and volume of aquaculture plantings. However, these reports are required only for holders of leases managed by CDFG. Additionally, differences in the reporting requirements over time make it impossible to evaluate trends in aquaculture practices even for this subset of aquaculture facilities.*

A subset of aquaculture farms, the holders of leases managed by CDFG, are required to submit Proof of Use (POU) reports indicating the number and identity of organisms planted and harvested each year. POU reports have been routinely used since the early 1980s when they overlapped with the required filing of Inspection and Planting Certificates (see above) and eventually replaced them. POU reports are composed of several components, and in their current form, they require the filer to list all planting and harvesting activities by date for the year, a map of the site, and a narrative of the activities. We entered all available CDFG lease POU records into a database.

Due to the above-mentioned limitations of available CDFG and USACE records, we were unable to determine the total number of aquaculture businesses or the volume of organisms actually placed in state waters currently or historically. However, data gleaned from the POU reports presented the opportunity for case studies of trends in California aquaculture.

We focused on one long-term CDFG leasee in Tomales Bay and all POU records pertaining to the CDFG lease allotments in Morro Bay and Santa Barbara. Even with these mostly complete data sets, changes in the way data were recorded (i.e. shifts from recording volume of species as cases vs. individuals, and from using calendar vs. fiscal years) makes comparisons challenging. POU statements do not need to include a list of sources for these plantings and organisms. For the older POU records (early to mid-1980s), there are few inspection and planting certificates that allow us to determine the origin of species being planted. In more recent years (1989 to 2011), some source information can be gathered from the import permits. The earlier records also indicate the amount of bay-to-bay transfers within the state, information that is no longer gathered.

Fig. 8 shows the planting records for Tomales Bay allotment M-430-05, and Fig. 9 presents all inspection and planting certificates and import permits issued for M-430-05 that we were able to collect. Prior to the early 1980s in-state transfer between bays was reported, and a large amount of movement between bays (Fig. 9 blue bars) can be seen from 1977 to 1982. The majority of this in state transfer to M-430-05 was from Monterey county (Elkhorn Slough/Moss Landing Harbor) and San Francisco. All three of these water bodies have high rates of species introductions attributed to aquaculture.

Although import permits indicate which species are approved for import from one source company/location, under current requirements, this does not mean the permitted species were actually imported. Additionally, the import permit does not need to specify number of individuals being imported. Thus, the ability to determine species composition and estimate volume planted from the import permits is limited. For example, Fig. 11 shows the plantings listed on the POUs for CDFG-operated leases in the Santa Barbara area from 1988 to 2010. When comparing these plantings from 1989 to 2010 with the import permits for this destination, the plantings and imports are not congruent (Fig. 12). For example, Santa Barbara companies received an import permit for *M. galloprovincialis* in 2004, however, these companies probably did not import this species, since no plantings of this species occurred until 2006 according to Proof of Use reports. Additionally, these aquaculture facilities planted *M. galloprovincialis* every year from 2006 to 2010, but they received permits to import from out of state for only years 2004, 2006, 2008, and 2010. Therefore, due to the incongruences and lack of reporting on the POUs and import permits, it is often difficult to assess the actual flux of species and individuals entering the state, and as such estimate propagule supply.

Tomales Bay

All water bottom lease allotments in Tomales Bay were historically and are currently held by CDFG. Proof of Use records exist for Tomales Bay lease allotments from the late 1970s to present. Within Tomales Bay, allotment M-430-05 has the most consistent set of records available for this time period. Table 5 and Fig. 8 present the volume of oysters planted over the time period 1977, 1983, and 1985-2010 by species. Fig. 9 shows possible planting species origins from 1977 to 2008, as presented in the Inspection and Planting Certificates and Import Permits. Before 1982, reported species sources included locations within California, US East and West Coasts and oversea locations; after 1989 imports were primarily from Washington with two years, 1989 and 1999, having imports from Alaska and one year, 1994, having an import from Australia. Over this time period, *Crassostrea gigas* was the dominant species planted. The European flat oyster *Ostrea* *edulis* (in 1977, 1985, 1986, 1994, 1995), the Eastern oyster *C. virginica* (in 1977), and the Kumamoto oyster *C. sikamea* (in 1985) were also planted during this time. However, the Kumamoto oysters may not have always been reported separately from *C. gigas.* In addition to oyster plantings, the mussel *M. galloprovincialis* was planted in 1991 and 1993 (350 pounds and 50 strings, respectively).

We used the data from Tomales Bay to determine whether there has been any change over time in the quantity of imports into this site. Using the data from Fig. 9, we tested the difference in the numbers of import permits before vs. after 2000. We found no significant difference in the number of import permits prior vs. post 2000 (t-test; $t_7 = -0.19$, $p>0.85$) suggesting that the quantity of imports of species in Tomales Bay has not declined.

Table 5. Subtotals for plantings by species (in thousands of individuals of seed) for Tomales Bay allotment M-430-05 by year. *1977 and 1983 represent fiscal year July-June of following year.

Year*	*C. gigas*	*C. gigas* (Kumumoto)	*C. virginica*	*O. edulis*
1977	656.5	0	15	87.3
1983	0	0	0	0
1985	908	5	0	50
1986	729.5	0	0	210
1987	834.3	0	0	0
1990	606	0	0	0
1991	786	0	0	0
1992	832	0	0	0
1993	1649	0	0	0
1994	660	0	0	22
1995	742.75	0	0	150
1996	860	0	0	0
1997	806	0	0	0
1998	1761.6	0	0	0
1999	2952.8	0	0	0
2000	1932	0	0	0
2001	872	0	0	0
2002	1770	0	0	0
2003	814.5	0	0	0
2004	775.175	0	0	0
2005	815.929	0	0	0
2006	700.5	0	0	0
2007	589	0	0	0
2008	1436	0	0	0
2009	1255	0	0	0
2010	1450	0	0	0

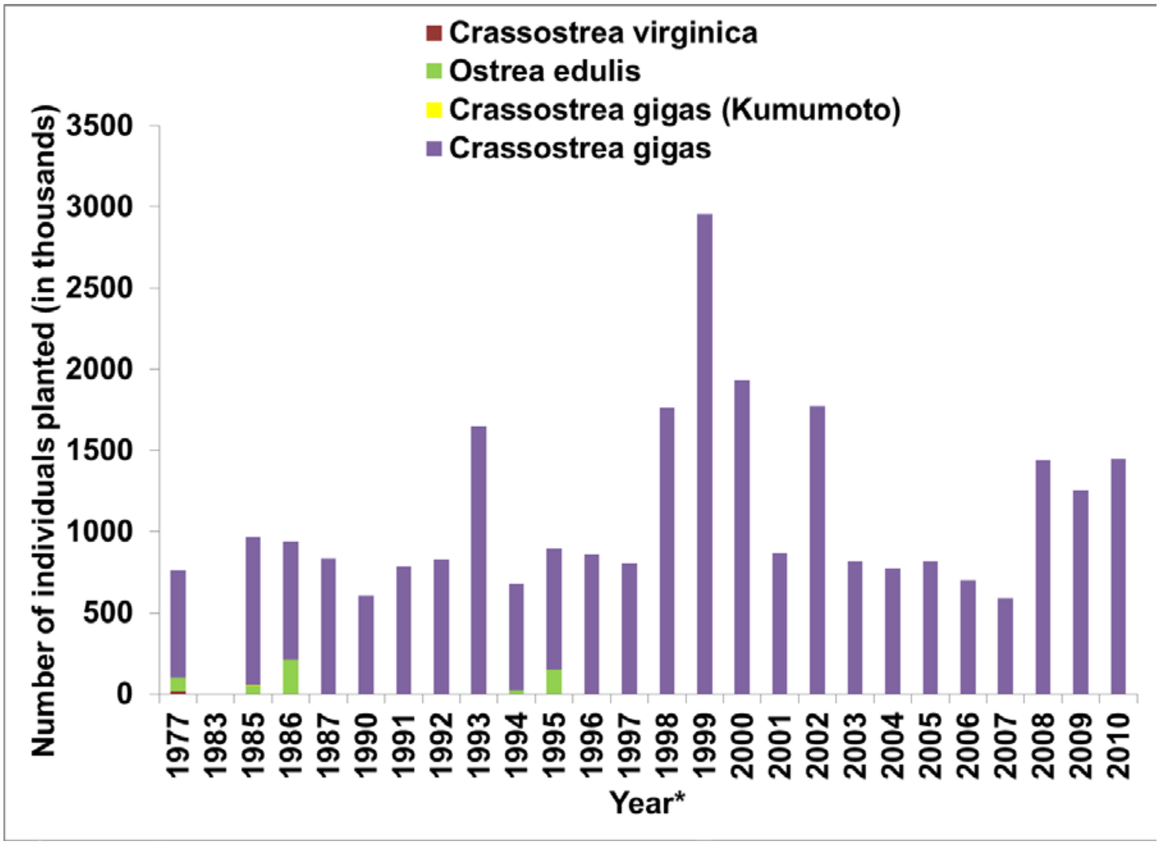

Figure 8. Time series of oyster seed aquaculture plantings in Tomales Bay allotment M-430-05. Missing years represent missing data rather than no activity. *1977 and 1983 represent fiscal year July-June of following year. Data source: California Department of Fish and Game.

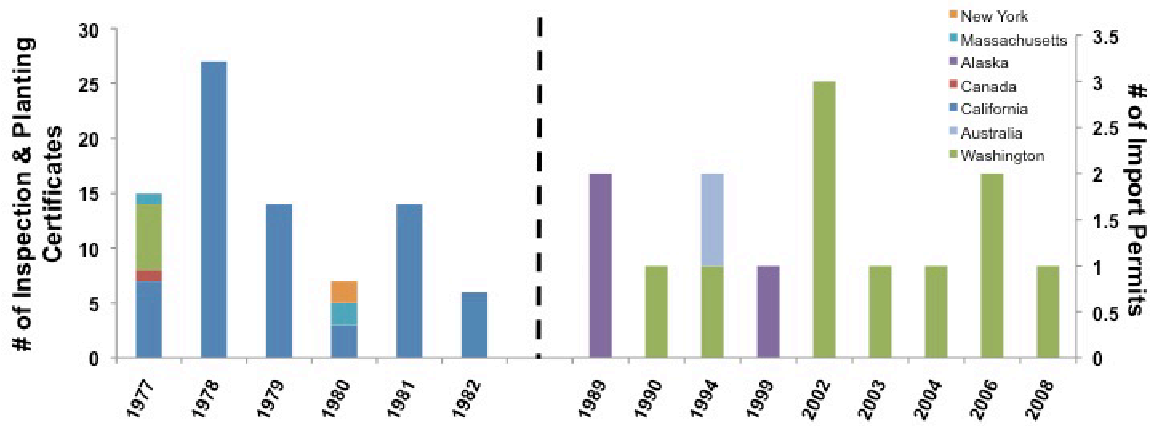

Figure 9. Time series of import locations for Tomales Bay lease allotment M-430-05. 1977 – 1982 import origins were determined from Inspection and Planting Certificates (y-axis on left). These certificates were necessary for each individual planting at this location. 1989 to 2008 import origins were determined via the import permits (y-axis on right). These permits were only necessary to file once per year for each import origin. Data source: California Department of Fish and Game

Box 2. Aquaculture in Tomales Bay. This bay located 100 miles north of San Francisco has been the recipient of many non-native species associated with aquaculture beginning with the importation of Olympic oysters from Washington. Many species have been introduced into Tomales Bay including Pacific oysters, European flat oysters, Eastern oysters, Manila clams and several others. Many significant hitch hikers including oyster predators (whelks, oyster parasites) have become established though the non-native oysters did not. The import data is among the most complete and typical of many other bays. The pattern here is one of recent increases in imports of Pacific oysters but from a decreasing number of sources now primarily Washington.

Morro Bay

Proof of Use records are available for the two CDFG water bottom lease allotments in Morro Bay. Table 6 and Fig. 10 present planting records from Proof of Use statements for all species planted in all of the Morro Bay allotments. While the record is not as complete as for Tomales Bay, it provides an overview of activities between the late 1970s and 2010. Species listed only as "oyster," *C. gigas*/Pacific oyster, *Mytilus edulis,* and bay mussels were planted over this time period. The most recent planting records for *C. gigas* differentiate diploid and triploid individuals to some extent. In 2009, 16.8% of reported *C. gigas* plantings were reported as diploid and 21.2% were reported as triploid, with the remaining percentage unspecified. In 2010, the numbers were 60.0% and 29.1% for diploids and triploids, respectively. For other years, ploidy was not reported. The records from Morro Bay illustrate the inconsistency through time of how volumes were reported (cases before 1988 and individuals from 1989 onward), and that occasionally species planted for aquaculture are wild caught rather than imported.

Table 6. Subtotals for plantings by species for Morro Bay by year. *1971-1989 represent fiscal year July to June of following year; 1996-2010 represent 9calendar year. 1971-1988 volumes are in cases; 1989-present volumes are in seed/individuals.

Year*	*C. gigas*	*C. gigas* (diploid)	*C. gigas* (triploid)	*C. gigas* (case)	Oyster (case)	Bay mussels	Bay mussels (wild caught)	*M. edulis*
1971	0	0	0	0	4.1	0	0	0
1972	0	0	0	0	0	0	0	0
1973	0	0	0	0	1.4	0	0	0
1974	0	0	0	0	1	0	0	0
1975	0	0	0	0	3.6	0	0	0
1976	0	0	0	0	0	0	0	0
1988	0	0	0	0.2	0	0	0	0
1989	0	0	0	0	0	0	0	200
1996	349	0	0	0	0	0	0	0
1999	130	0	0	0	0	0	0	0
2002	49	0	0	0	0	0	0	0
2003	100	0	0	0	0	15	0	0
2004	3554	0	0	0	0	15	0	0
2005	4350	0	0	0	0	10	0	0
2006	1421.5	0	0	0	0	0	0	0
2007	1668	0	0	0	0	0	0	0
2008	1055	0	0	0	0	0	5	0
2009	535	210	200	0	0	0	0	0
2010	410.7	567	275	0	0	0	0	0

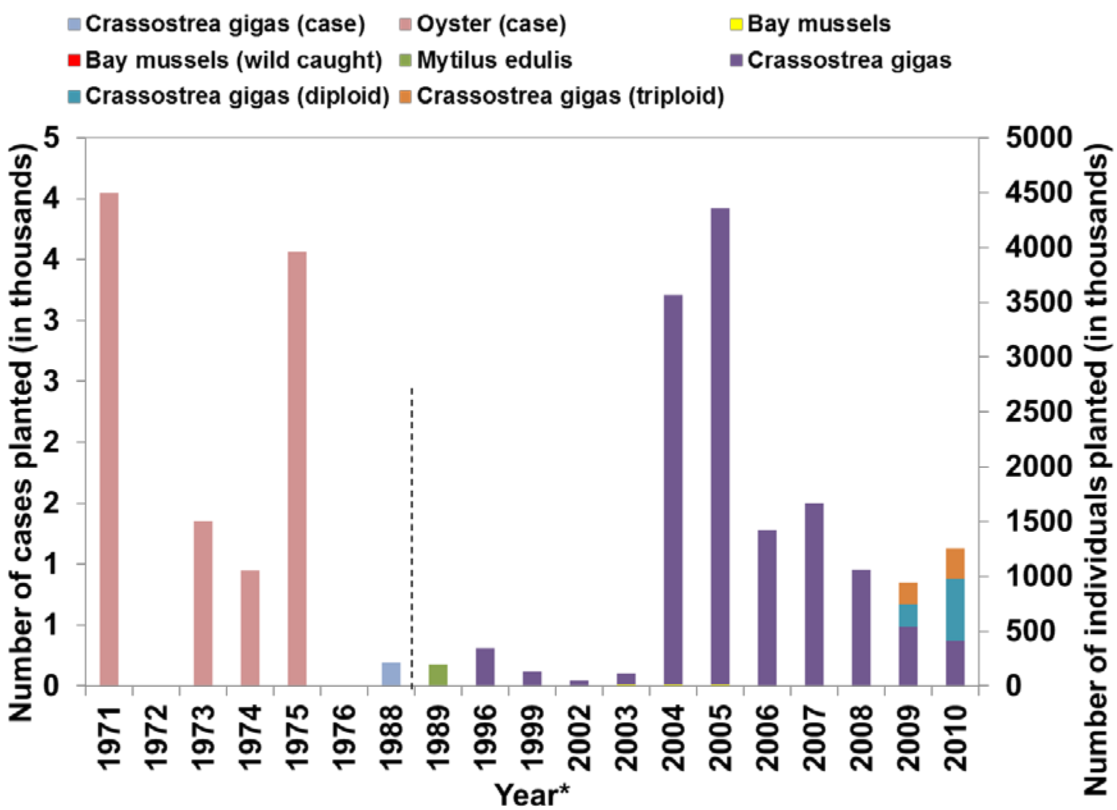

Figure 10. Time series of aquaculture plantings at a Morro Bay lease managed by CDFG in thousands of cases (left) and thousands of individuals (right). Dashed line indicates the change in the way volume was reported. 1971-1988 volumes are in cases; 1989-present volumes are in seed/individuals. Missing years represent missing data rather than no activity. *1971-1989 represent fiscal year July to June of following year; 1996-2010 represent calendar year. Data source: California Department of Fish and Game.

Santa Barbara

Eight different species types were reported by leaseholders as planted in the Santa Barbara Proof of Use records. Within Santa Barbara, Proof of Use reports were filed for 10 lease sites at least once between 1971 and 2010, with planting activity occurring in four. While *C. gigas* was planted most often but in small amounts, mussel species were the most prevalent in terms of volume (Table 7 and Fig.11). This is especially true since 2006. *Haliotis rufescens* (red abalone) was planted in 1988 and 1989, *C. virginica* was planted in 2001, and *V. philippinarum* in 2003. While both names are used, *M. galloprovincialis* and "Mediterranean mussels" appear to be the same species. Corresponding import permits exist for 2004, 2006, 2008, and 2010 for *M. galloprovincialis* from Whiskey Creek Shellfish Hatchery in Oregon and Taylor Shellfish in Washington (Fig. 12).

Table 7. Plantings by species for Santa Barbara by year (in thousands). Mediterranean mussels and *Mytilus galloprovincialis* are recorded in number of mussels set on ropes.

Year	*C. gigas*	*C. virginica*	*M. edulis*	*Macrocystis angustifolia*	Med. mussels	*M. gallo-provincialis*	*Haliotis rufescens*	*V. philippinarum*
1988	0	0	0	0	0	0	35.002	0
1989	50	0	2000	0	0	0	15.7	0
1996	0	0	0	10	0	0	0	0
1997	200	0	0	0	0	0	0	0
1998	75	0	0	0	0	0	0	0
2001	50	75	0	0	0	0	0	0
2002	300	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	30
2004	180	0	0	0	0	0	0	0
2005	160	0	0	0	0	0	0	0
2006	90	0	0	0	0	6600	0	0
2007	50	0	0	0	6000	0	0	0
2008	200	0	0	0	0	360	0	0
2009	100	0	0	0	2800	0	0	0
2010	285	0	0	0	1000	0	0	0

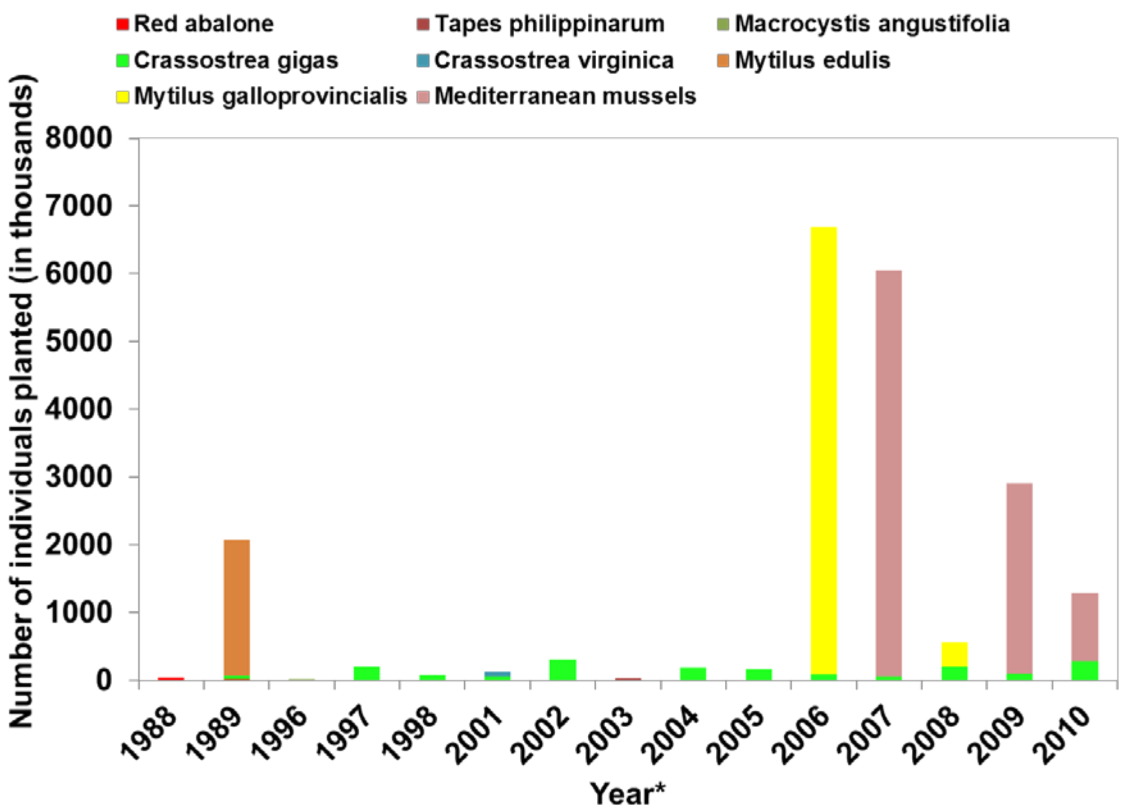

Figure 11. Time series of oyster seed aquaculture plantings in Santa Barbara allotments. *Missing years represent missing data rather than no activity. Mediterranean Mussels and *Mytilus galloprovincialis* are recorded in number of mussels set on ropes. Data source: California Department of Fish and Game.

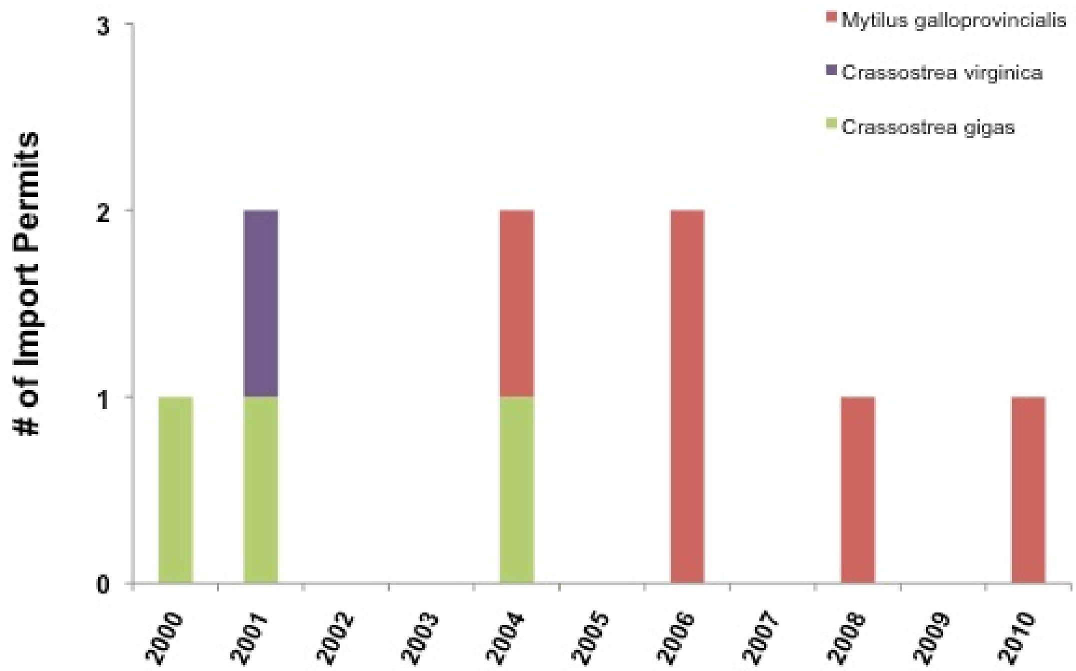

Figure 12. Time series of import permits by species issued for Santa Barbara lease allotments. The import permits issued irregularly corresponds to what is actually planted and/or imported causing an over estimate of species brought in from out of state. Data source: California Department of Fish and Game.

3.2 US Army Corps of Engineers Aquaculture-Related Permits

***Key finding** – Most, if not all, aquaculture facilities require a permit from the US Army Corps of Engineers. However, exactly which permits are required is unclear, compliance is low, and records for aquaculture facilities are not kept by ACOE in a retrievable manner.*

Aquaculture businesses placing structures that change the flow of water, pose navigation hazards, discharge fill material, and/or affect the substrate are required to obtain federal permits through the Army Corps of Engineers. The ACOE has regulatory authority under of the Clean Water Act of 1972, Section 404 and the Rivers and Harbors Act of 1890.

All proposed discharges of dredged or fill material occurring below the plane of ordinary high water in non-tidal waters of the United States; or below the high tide line in tidal waters of the United States; and within the lateral extent of wetlands adjacent to these waters, typically require Department of the Army authorization and the issuance of a permit under Section 404 of the Clean Water Act of 1972, as amended (33 U.S.C. § 1344 *et seq*.).

Proposed structures and work, including excavation, dredging, and discharges of dredged or fill material, occurring below the plane of mean high water in tidal waters of the United States; in former diked baylands currently below mean high water; outside the limits of mean high water but affecting the navigable capacity of tidal waters; or below the plane of ordinary high water in non-tidal waters designated as navigable waters of the United States, typically require Department of the Army authorization and the issuance of a permit under Section 10 of the Rivers and Harbors Act of 1899, as amended (33 U.S.C. § 403 *et seq*.).

Prior to 2007, all new aquaculture structures and subsequent changes to in-water aquaculture facilities needed to have an approved USACE Nationwide Permit 27 and 4 (NWP27 'Aquatic Habitat Restoration, Establishment, and Enhancement Activities' and NWP4 'Fish and Wildlife Harvesting, Enhancement, and Attraction Devices and Activities'). Once a new structure is approved via NWP27 a monitoring period of five years by USACE occurs. This monitoring time period can be shortened or extended depending USACE findings. NWP4 authorized seeding within these approved aquaculture facilities. [Authors' note: the exact permits required are unclear to us. We received conflicting information from different ACOE offices as to which types of permits are required.]

Any commercial aquaculture facility bottom lease in place prior to the Clean Water Act of 1972 was grandfathered in and did not need to file a NWP27. As long as the lease has been continually owned, even with various leasees, then an NWP27 exemption exist. However, beginning in 2007, all pre-existing aquaculture facilities had to acquire a new Nationwide Permit 48 (NWP48 'Existing Commercial Shellfish Aquaculture Activities'). This permit approves the continued use of pre-existing structures, along with the discharge from these aquaculture facilities. This permit is valid for a 5-year period; when the permit is issued a report must be submitted at the beginning of this period by the facility owner to the local USACE district engineer. This report includes acreage, location, brief description of culturing/harvesting methods, species, and whether canopy predator nets are used. Prior to obtaining an NWP48 permit, the aquaculture facility owner must also submit a pre-construction notification to the local district engineer if the aquaculture acreage is greater than 100-acres, the operation is being enhanced or expanded, there is a change to species cultivated or culture methods, or area is dredged/tilled in areas near aquatic vegetation. Currently, NWP48 is still in use, however, beginning in late 2012, the reporting requirements are no longer in place and the pre-construction notification standards have been lessened. NWP48 permits must be renewed every 5 years; the ACOE acknowledges that many aquaculture facilities are not in compliance with the requirement to renew.

Our site visit to the Los Angeles USACE district office provided us with records from 1993 to 2011. Very few NWP27 records pertaining to aquaculture-related activities for the southern California USACE district and zero NWP48 records were available to us during our visit. Los Angeles USACE only had six permit requests pertaining to non-restoration aquaculture-related activities for southern California. This included four offshore aquaculture permits that were denied or withdrawn and two permits for nearshore salmon pens and abalone culturing facilities that were approved. As mentioned above, the San Francisco office was unable to provide us with records pertaining to aquaculture for Northern California.

3.3 Introductions Attributable to Aquaculture

Key Findings *- Eight of the fourteen intentionally placed non-native species (57%) have established populations in at least one location in the state. Both triploid and diploid oysters (C. gigas) are being imported for aquaculture; importers do not need to indicate ploidy status on permits.*

- One hundred twelve species are thought to have been accidentally introduced via aquaculture; of these 99 have become established.

-Eighty-three of the 126 species thought to have been introduced via aquaculture are "polyvectic;" aquaculture is likely the sole vector for 43. Of the 43 species assigned solely to the aquaculture vector, 21 are established (49%), 14 are failed introductions (33% not established anywhere in the state) and 7 are presently unknown (16%).

Aquaculture industry practices have dramatically reduced the risk of introductions into California, however, aquaculture still represents a small but significant risk.

Intentional Introductions

Our data shows 22 species have been used for commercial aquaculture in the state, based on past and current records held by CDFG (Table 8). Nearly all of these are non-native bivalves, but some native mollusc and algae species have also been used. Four non-native aquaculture species have become established in California: *Mya arenaria, Venerupis philippinarium, Mytilus galloprovincialis* (which hybridizes with native mussels) and *Mercenaria mercenaria.* The Pacific oyster, *Crassostrea gigas,* represents the single greatest number of permits (Fig 3.1). NEMESIS lists the population status of *C. gigas* as unknown; however several cohorts from wild populations have been documented in San Francisco Bay (Cohen & Weinstein 2008, Goodwin et al. 2010) and have been the focus of an eradication effort. The source of these wild populations is unknown. Although *C. gigas* has not been commercially raised in San Francisco Bay for several decades, unofficial private stocking attempts, which continue to this day (CJZ, EDG personal observations) may be the source of propagules. Large oysters, clearly non-native species, are also present in San Diego Bay (CJZ personal observation) and a *C. gigas* cohort was genetically identified in San Pedro near the Port of Los Angeles Harbor (D. Hedgecock, University of Southern California; J. Moore, CDFG) (see Box 2 below). These sites may represent single, non-reproductive cohorts.

Venerupus philippinarum and *Crassostrea sikamea* are second and third highest in terms of approved permits. Although many individuals of particular species such as

Crassostrea gigas are brought into California, it is impossible to know exactly how many. Among our most important finding is the lack of detail in permitting records both with respect to species identity as well as any usable estimate of numbers of these species.

Private stocking permit records indicate that several additional species have been planted in state waters outside of registered commercial aquaculture facilities. Most of these are species of abalone (*Haliotis* spp.), keyhole limpets (*Megatura crenulata*) and native and non-native oysters and mussels. In some cases, the permits describe the animals to be planted only as "oysters" "clams" or "abalone," in other cases species names were used (Table 8). Many of the permit-holders are research institutions. Thirty-eight such permits were issued over the 17-year period for which records exist.

Triploid oysters are widely used in aquaculture. Within California, aquaculture importers do not need to specify whether the organisms they are importing are diploid or triploid, but this status was noted in some cases. Of the total import permits for aquaculture purposes (1989 to 2011), 75% contain at least one oyster species, and of these, triploid or diploid status is only stated on 6 (2.4%). On all permits where this status was specified, importers only stated triploid or diploid for the oyster species, *Crassostrea gigas*. Even when considering only permits that import *C. gigas*, triploid/diploid is only specified on 3.1% of the *C. gigas* import permits.

Table 8. Species used in California commercial aquaculture between 1964 to 2011, based on import permits, proof of use reports, and inspection and planting records held by CDFG. Species in bold are non-native species that have become established in the state; the status of *C. gigas* is listed as uncertain by NEMESIS, but reports suggest that it is established in at least one bay and perhaps in additional locations (see Box 2 below).

Species	**Common name**
Panularis interruptus	spiny lobster
Haliotis rufescens	red abalone
Haliotis discus hannai	Japanese abalone
Patinopecten caurinus	scallop
Panopea generosa	geoduck
Palmaria mollis	red algae
Nereocystis luetkeana	bull kelp
Mercenaria mercenaria	quahog
Ostrea edulis	European flat oyster
Ostrea lurida	Olympia oyster
Mytilus galloprovincialis	Mediterranean mussel
Mytilus edulis (species complex)	Bay mussel
Venerupis philippinarum *(=Tapes japonica)*	Japanese littleneck

Ruditapes decussatus (=Tapes decussatus)	checkered carpet shell
Crassodoma gigantea	purple hinged rock scallop
Crassostrea rivularis	Suminoe oyster
Crassostrea virginica	Eastern oyster
Crassostrea sikamea (= *Crassostrea gigas sikamea*)	Kumamoto oyster
Crassostrea gigas	Pacific oyster
Cancer magister	Dungeness crab
Mya arenaria	soft-shell clam

Unintentional Introductions

The list of unintentional introductions is of course much longer than the list of intentional vectors. We found 126 non-native species potentially associated with aquaculture reported from the state of California (Appendix I). One hundred and six species have become established in at least one location in the state.

Fourteen species of these were intentionally placed into state waters in at least one location. Most were raised commercially, but at least two, the clam *Corbicula fluminea* and the mitten crab *Erocheir sinensis,* are thought to have been planted unofficially by individuals hoping to start a harvestable population. The remaining 112 non-native species were accidental introductions. These include some of the most damaging species including the Atlantic (*Urosalpinx cinerea*) and Japanese oyster drills (*Ocinebrellus inornatus*), which subsequently became pests of both cultured and native oysters. Also, the sabellid polychaete shell parasite of abalone *Terebrasabella heterouncinata* was a serious pest of cultured abalone and required the extermination of large numbers of cultured stocks to ensure eradication in culture facilities.

As pointed out above, eight of the fourteen intentionally placed species (57%) have established populations in at least one location in the state, five have failed. The status of one species, *Crassostrea gigas,* is unknown according to NEMESIS, however several reports indicate it may be established in at least one location (see Box 2). This ratio is significant because it can be used to estimate the likelihood of establishment given introduction by the intentional aquaculture subvector. For most vectors (including the accidental aquaculture subvector), it is very rare that a species that is introduced but not established is reported.

By comparison, ninety-nine of the accidentally introduced species (88%) have become established. Most (83) of the 126 species associated with aquaculture are polyvectic, which as defined in Methods means aquaculture was one of several possible vectors. Of the remaining 43 species, aquaculture is the sole vector believed to be responsible for their introduction. Of the 43 species assigned solely to the aquaculture vector, 21 are established (49%), 14 are failed introductions (33% not established anywhere in the state) and 7 are presently unknown (16%). One species, the tubeworm *Terebrasabella* *heteruncinata* is now extinct, due to a massive eradication effort (Culver and Kuris 2000).

3.4 Spatial and Temporal Trends in Aquaculture Introductions

Key Findings *– The number of accidentally introduced species associated with aquaculture does not appear to be declining significantly. However, most new introductions in the past few decades have polyvectic, which might mask a signal of better management practices by aquaculture. Although current aquaculture industry practices have dramatically reduced the risk of unintentional introductions (hitch hikers), several have been introduced since 2000, including four flatworms with aquaculture as the sole attributed vector, after these industry practices were firmly in place. Also, the risk of introduction for target species such as* Crassostrea virginica *remain.*

- Most of the non-native species associated with aquaculture have been reported from central and northern California, however, such introductions are widely distributed throughout the state.

Temporal Patterns of Aquaculture Introductions

The first report of a non-native species introduced to California by the aquaculture trade was in 1875 (NEMESIS) and new reports of aquaculture-related introductions continued over the next several decades Introductions solely attributed to aquaculture increased from 1941-1950 to a peak in 1971-1980, however new introductions continue through the present (Fig. 13). There does not appear to be a declining trend in species for which aquaculture is one possible mode of introduction (polyvectic): reports of these species were highest in 1890-1899, 1940-1949 and 1950-1959.

The analyses discussed above (see Section 3.1.2 and 3.1.5) demonstrate that there has not been a significant decline in the number of permits either statewide or into well studied Tomales Bay. If these are a reasonable proxy for the quantity of non-native species being imported into CA, the current risk for new introductions may still be significant, albeit much lower than the risk historically due to low-risk industry practices.

Spatial Patterns of Aquaculture Introductions

Aquaculture-linked invasions are widespread throughout the state although the vast majority is located in central and northern California (Fig. 14). San Francisco Bay has the largest number of established non-native species thought to have been introduced via aquaculture: 30 are linked solely to aquaculture, and 62 that are polyvectic with aquaculture as a possible vector. Three bays with a long history of aquaculture also have high numbers of such species: Tomales Bay (20 sole vector, 28 polyvectic), Elkhorn Slough (14 sole, 37 poly), and Humboldt (13 sole, 38 poly). Several other locations were aquaculture activities have or are occurring have high number of such species, including Morro Bay, Drakes Estero and Bodega Bay. Somewhat surprisingly, the coastal area between Drakes Estero and Tomales Bay also had 18 species linked to aquaculture (Fig.

14). Nine other water bodies and coastal areas, not shown in the figure below, each have 1-2 non-native species linked to aquaculture.

Most of the state's first records of non-native species linked to aquaculture are from San Francisco Bay, with Tomales Bay and Elkhorn Slough showing the next highest numbers of these species (Fig. 15). Two major aquaculture areas, Humboldt and Morro Bay, do not have many of the state's first records, although they have high numbers of species introduced by aquaculture; this may be an artifact of where the most taxonomists were working (Fig. 15).

On a bay-by-bay basis, species invasions linked to aquaculture generally seem to have dropped since 1980s, although this is not true in all cases (Table 9, Appendix I). Decades with the highest numbers of new reports for each bay generally reflect the publication dates surveys or other taxonomic work (*e.g.* Wasson *et al.* 2001 for Elkhorn Slough, Boyd *et al.* 2002 for Humboldt Bay), rather than decades in which new introductions were particularly high. However, the number of new records for San Francisco Bay was high in the time period prior to publication of a major dissertation that involved an extensive survey there (Carlton 1979), suggesting that introductions in SF Bay have been relatively well-studied over the course of many decades.

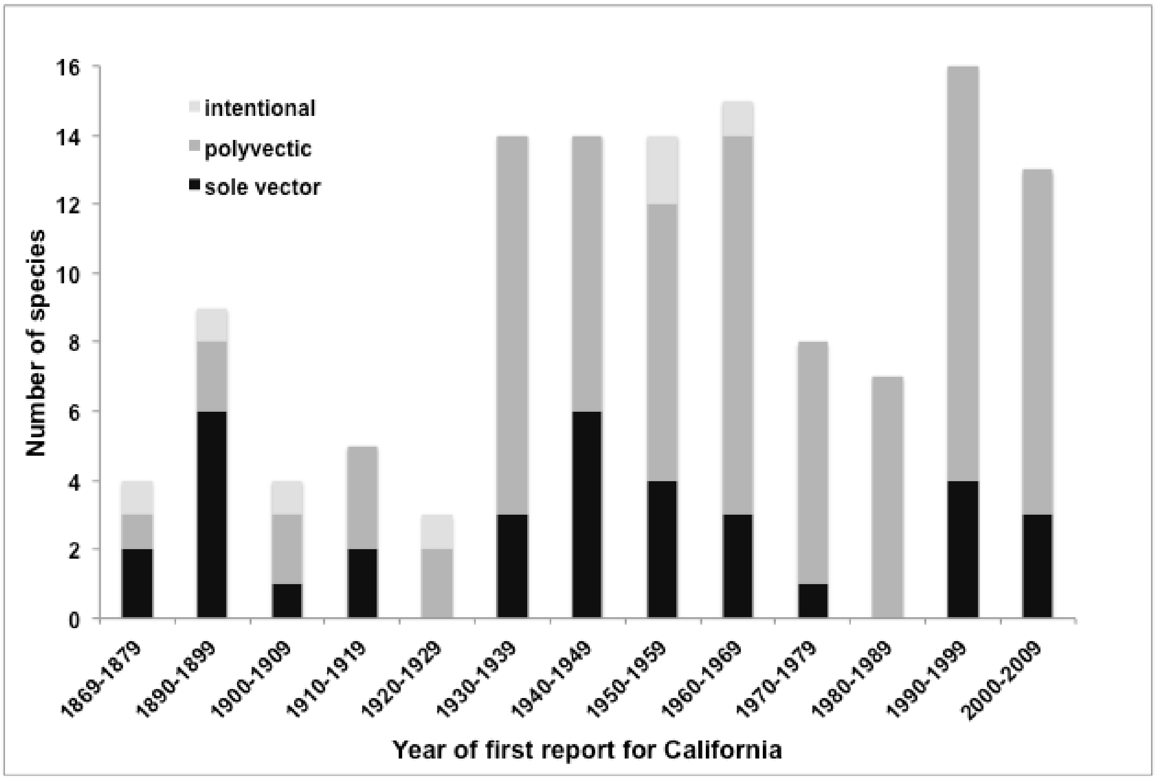

Figure 13. The number of species thought to have been introduced to California by aquaculture. Light gray bars represent intentional introductions; dark gray bars represent accidental introductions where aquaculture is one of several likely vectors; black bars represent accidental introductions attributed solely to aquaculture. Year of first report in the state (where aquaculture is a suspected vector) is used as a proxy for year of introduction by this vector. Data are from NEMESIS (Smithsonian Environmental Research Center).

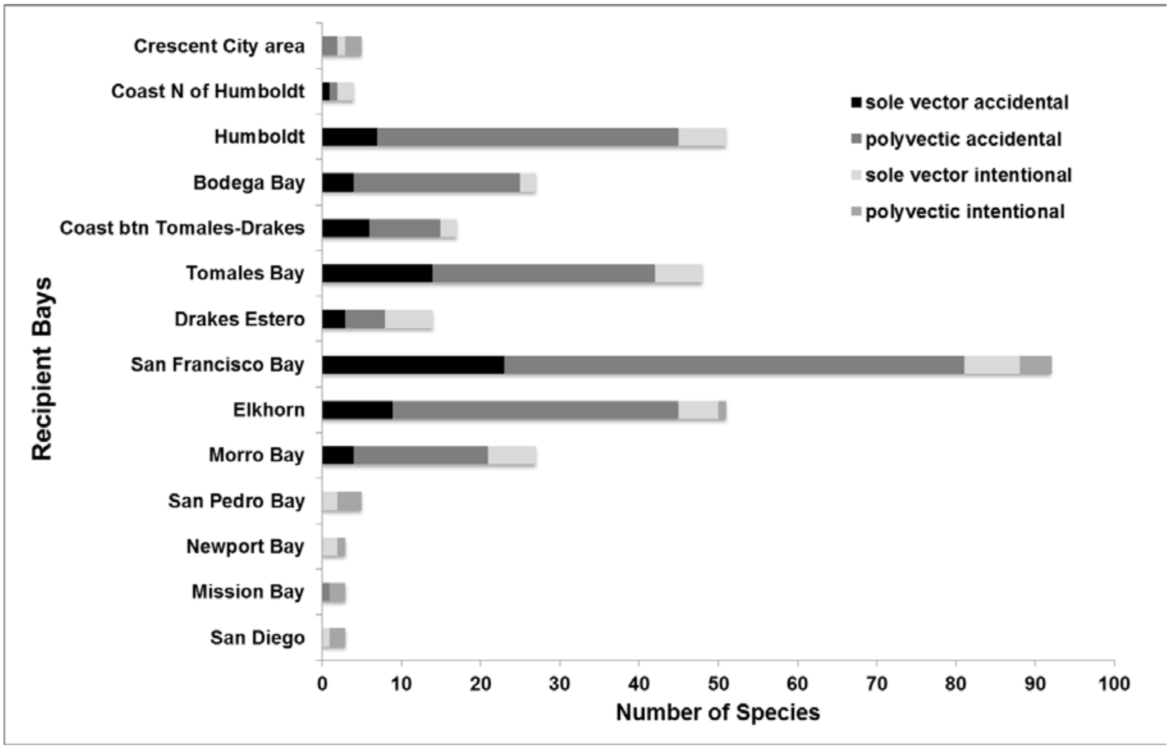

Figure 14. The number of species believed to have been introduced to California by aquaculture listed by location from north to south. Black bars represent accidental introductions attributed solely to aquaculture; dark medium gray bars represent accidental introductions where aquaculture is one of several likely vectors; light gray bars represent intentional introductions attributed solely to aquaculture; light medium gray bars represent intentional introductions where aquaculture is one of several likely vectors. Locations with fewer than two species were not plotted. San Francisco Bay has the most species linked solely to aquaculture as well as those possibly linked. Humboldt, Tomales, Bodega and Morro Bays and Elkhorn Slough also have high numbers. Data are from NEMESIS (Smithsonian Environmental Research Center).

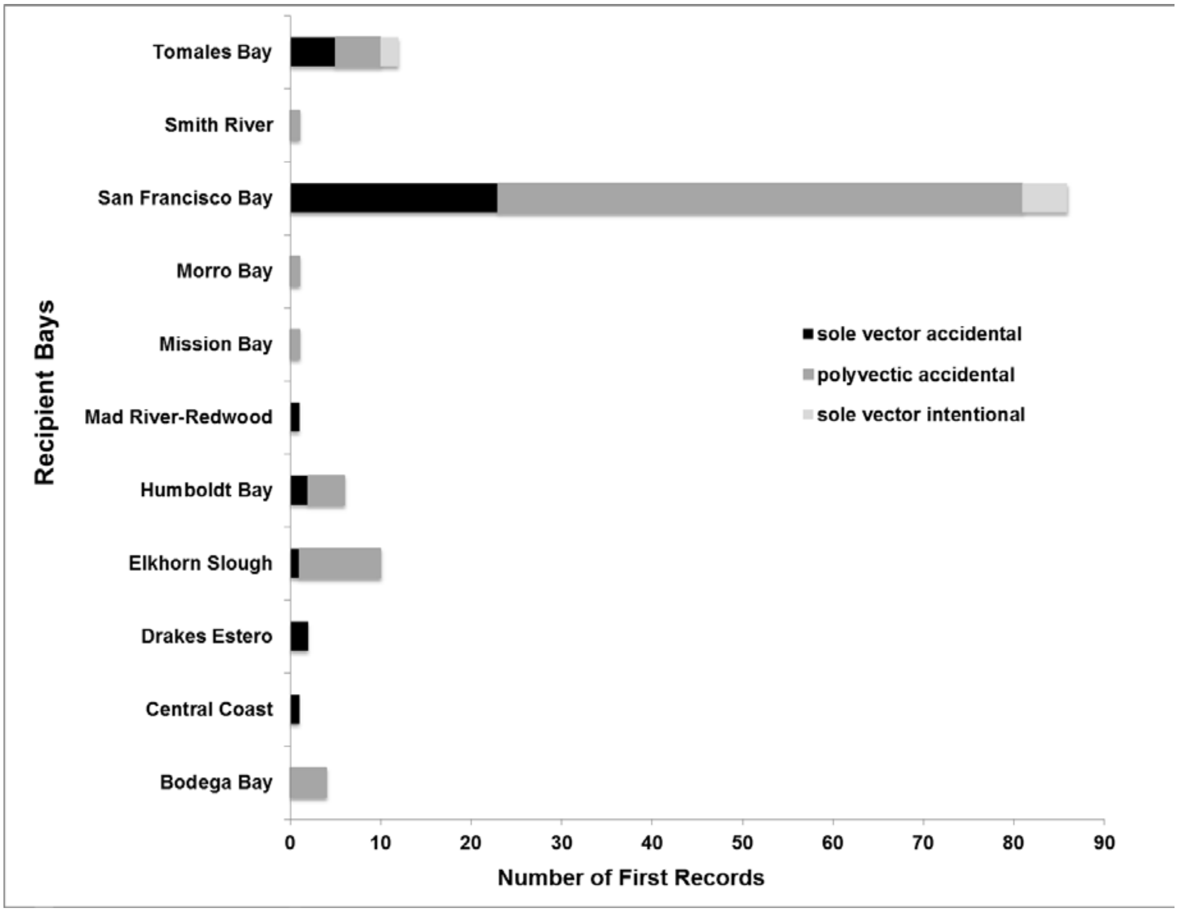

Figure 15. The number of first records of non-native species thought to have been introduced to California by aquaculture. Black bars represent accidental introductions attributed solely to the aquaculture vector; dark gray bars represent accidental introductions where aquaculture in is one of several likely vectors; light gray bars represent intentional introductions via aquaculture. San Francisco Bay clearly leads the state in the number of first records of species associated with aquaculture. Data are from NEMESIS (Smithsonian Environmental Research Center)

Table 9. The number of non-native species linked to aquaculture reported from selected California bays and waterways, by time period. Waterways with fewer than three introduced species are excluded. Species attributed solely to aquaculture and those for which aquaculture is one of several possible vectors are combined in this table. Data are from CA NEMESIS. A gradient of yellow to red is used to indicate time periods with the lowest to highest numbers of species. Note: the last two columns represent a shorter time span than the previous columns. Current aquaculture practices to reduce accidental introductions were being widely practiced by 2000. There is no clear indication of an immediate reduction in numbers of newly reported species linked to aquaculture in the decade that followed. However, this table must be interpreted with caution as high numbers within a time period may be more reflective of more careful study of a region than of actual new introductions. For example, surveys by Boyd et al. in Humboldt Bay (published in 2002) and Wasson et al. (published in 2001) undoubtedly contributed to the high number of new reports in these locations during 1991-2000 (highlighted with diagonal lines).

Bay	to 1910	1911-1930	1931-1950	1951-1970	1971-1990	1991-2000	2001-2010
Smith River		1		1	2		1
Mad Redwod	1	1	1		1		
Humboldt Bay	2	1	4	7	10	15	6
Bodega Bay		1	4	2	9	6	5
Tomales Bay	1	3	11	15	3	6	9
Coast btn Tomales & Drakes		4	1	6	6	1	
Drakes Estero		1	2	5	3	1	2
San Francisco Bay	15	9	22	21	12	4	8
Elkhorn Slough	2	4	5	10	13	14	3
Morro Bay		1	4	10	5	3	4
San Pedro Bay				3		2	
Newport Bay			2			1	
Mission Bay					1	1	1
San Diego	1			1		1	

Box 3. Impacts of Pacific Oysters. The commercially grown Pacific oyster *Crassostrea gigas* represents one of the most important commercial shellfish species in California, but also represents one of the most likely aquaculture species to become established in many areas of California. If conditions allow its establishment and spread, native Olympia oysters *Ostrea lurida*, which are limited in their abundance throughout the state may be impacted. In fact, *C. gigas* has been shown to have significant impacts in locations around the world where feral populations have become established (NAS 2003), including in Washington (Ruesink et al. 2005). Global warming is likely to increase the likelihood of *C. gigas* spreading to this region (Diederich et al. 2005). Recent studies have shown it has colonized marine reserves and can be more abundant than in adjacent non-reserves. Recently, what may be established populations have been tentatively identified in San Francisco Bay (Goodwin et al. 2010) and in southern California in San Pedro near the Port of LA (California Dept. of Fish and Game). However, these may represent only single, non-reproductive cohorts. These populations have not been carefully tracked over time and their status is currently uncertain. The continued use of fertile diploid oysters and the possibility of reversion of sterile triploid oysters to fertile diploids (Zhang et al. 2010) contribute to the risk of possible establishment of feral *C. gigas* populations with potentially significant ecological impacts.

3.5 Impacts of NIS Introduced by Aquaculture Species

***Key Finding** –Introduced species associated with aquaculture were found to have significant impacts in a high percentage of studies of molluscs (75.5%) and algae (71%) with the majority being negative impacts on native species.*

Aquatic non-native algae and mollusc species were investigated for their ecological and economic impacts on non-native environments through peer-reviewed scientific literature searches. The non-native algae and mollusc species attributed to entering California waters via the aquaculture vector for which literature searches were conducted are listed in Table 10.

Only a small percentage of the peer-reviewed articles found during this literature search related to the impacts of these non-native species. Using the literature search terms listed in Section 2.5, BIOSIS returned 2080 and 317 articles for the mollusc and algae taxa, respectively. From these BIOSIS searches, only 3.4% (71 articles) of the peer-reviewed journal articles on molluscs contained studies on impacts. For the algae taxa, a larger percentage, 18.9% (60 articles) of the journal articles contained relevant impacts studies.

Few peer-reviewed studies have been conducted on the possible impacts of these molluscs species entering California state waters via the aquaculture vector. Nine of the 37 mollusc species attributed to this vector had at least one impact peer-reviewed journal article. Only six of these mollusc species (*Crassostrea gigas, Crepidula fornicata, Littorina littorea, Musculista senhousia, Mytilus galloprovincialis, Venerupis* *philippinarum)* had five or more peer-reviewed journal articles with impact studies. The impacts of these nine non-native mollusc species were measured in 61 peer-reviewed journal articles containing 122 studies. Of these studies, 77% reported an impact, while 24.5% did not report an impact of these non-native mollusc species on non-native environments and/or other species (Fig. 16). The most common impacts were on abundance and fitness of native species and the majority of those impacts were negative (Fig. 17)

In comparison to the mollusc taxa, fewer peer-reviewed journal articles were found via the BIOSIS literature searches for the algae taxa, however, a larger percentage of the articles found were related to impacts. Three of the seven non-native algae species (*Codium fragile ssp fragile, Gracilaria vermiculophylla, Sargassum muticum)* attributed to this vector, had more than five peer-reviewed journal articles discussing impacts. The other four non-native algae species attributed to this vector had very few articles found with the BIOSIS literature search (14 articles) and none contained impact studies. *Codium fragile ssp fragile, Gracilaria vermiculophylla,* and *Sargassum muticum* impacts were measured in 49 peer-reviewed journal articles containing 210 studies. Similar to the non-native mollusc species attributed to this vector, 84% of these studies reported an impact, while 16% did not report an impact of these non-native algae species on non-native environments and/or other species (Fig. 18). The most common impacts were on abundance and fitness of native species and the majority of those impacts were negative (Fig. 19).

Table 10. All algae and mollusc species entering into California via the aquaculture vector for which impact literature searches were completed. Species that were intentionally introduced for aquaculture purposes are highlighted in yellow; all others are unintentional introductions (hitchhikers).

Taxa	Species	Sole or Polyvectic	CA Status
algae	*Ceramium kondoi*	Poly	ESTABLISHED
algae	*Chondracanthus teedei*	Sole	UNKNOWN
algae	*Codium fragile ssp fragile*	Poly	ESTABLISHED
algae	*Gelidium vagum*	Sole	ESTABLISHED
algae	*Gracilaria vermiculophylla*	Poly	ESTABLISHED
algae	*Grateloupia lanceolata*	Poly	ESTABLISHED
algae	*Lomentaria hakodatensis*	Poly	ESTABLISHED
algae	*Sargassum muticum*	Poly	ESTABLISHED
mollusc	*Anadara ovalis*	Sole	FAILED
mollusc	*Anadara transversa*	Sole	FAILED
mollusc	*Anomia simplex*	Sole	FAILED
mollusc	*Argopecten irradians*	Sole	FAILED

mollusc	*Batillaria attramentaria*	Poly	ESTABLISHED
mollusc	*Boonea bisuturalis*	Poly	ESTABLISHED
mollusc	*Busycotypus canaliculatus*	Poly	ESTABLISHED
mollusc	*Corbicula fluminea*	Poly	ESTABLISHED
mollusc	*Crassostrea gigas*	Poly	UNKNOWN
mollusc	*Crassostrea virginica*	Sole	FAILED
mollusc	*Crepidula convexa*	Poly	ESTABLISHED
mollusc	*Crepidula fornicate*	Sole	FAILED
mollusc	*Crepidula plana*	Poly	ESTABLISHED
mollusc	*Eubranchus misakiensis*	Poly	ESTABLISHED
mollusc	*Gemma gemma*	Sole	ESTABLISHED
mollusc	*Geukensia demissa*	Poly	ESTABLISHED
mollusc	*Haminoea japonica*	Poly	ESTABLISHED
mollusc	*Ilyanassa obsolete*	Poly	ESTABLISHED
mollusc	*Littorina littorea*	Poly	UNKNOWN
mollusc	*Macoma petalum*	Poly	ESTABLISHED
mollusc	*Mercenaria mercenaria*	Poly	ESTABLISHED
mollusc	*Meretrix lusoria*	Sole	FAILED
mollusc	*Musculista senhousi*	Poly	ESTABLISHED
mollusc	*Mya arenaria*	Sole	ESTABLISHED
mollusc	*Myosotella myositis*	Poly	ESTABLISHED
mollusc	*Mytilus galloprovincialis*	Poly	ESTABLISHED
mollusc	*Nuttallia obscurata*	Poly	UNKNOWN
mollusc	*Ocinebrellus inornatus*	Sole	ESTABLISHED
mollusc	*Okenia plana*	Poly	ESTABLISHED
mollusc	*Ostrea edulis*	Sole	FAILED
mollusc	*Ostrea puelchana*	Sole	FAILED
mollusc	*Petricolaria pholadiformis*	Poly	ESTABLISHED
mollusc	*Philine japonica*	Poly	ESTABLISHED
mollusc	*Philine orientalis*	Poly	ESTABLISHED
mollusc	*Sakuraeolis enosimensis*	Poly	ESTABLISHED
mollusc	*Urosalpinx cinerea*	Sole	ESTABLISHED
mollusc	*Venerupis philippinarum*	Poly	ESTABLISHED

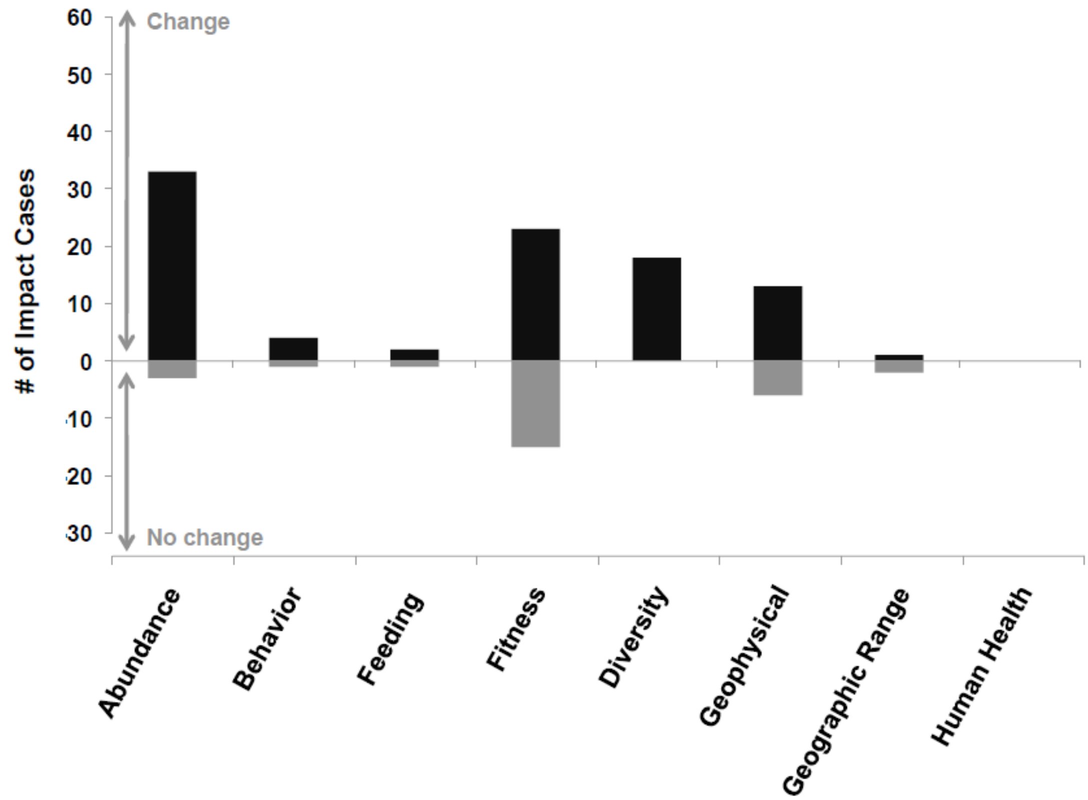

Figure 16. Summary of number of cases reported in the literature searched in which the presence of non-native mollusc species were associated with a change in a response variable. 'Change' includes a positive or negative difference in a response variable as well as responses that have no direction (upper black bars), such as a change in community structure vs. no impact (lower gray bars) on surrounding native communities or environments. See Appendix V for an explanation of data set and impact categories.

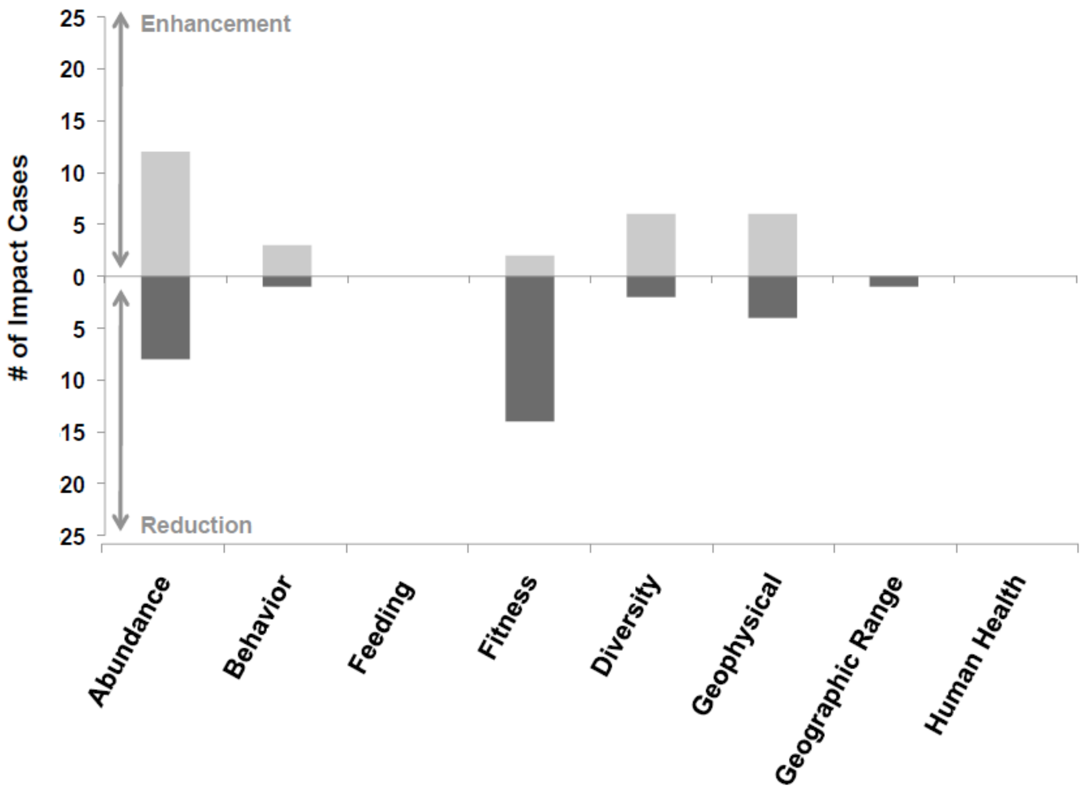

Figure 17. The number of studies (cases) for molluscs introduced by aquaculture that show either a significant positive impact ('Enhancement', upper black bars) vs. negative impact ('Reduction', lower gray bars) on surrounding native communities. See Appendix V for an explanation of data sets and impact categories.

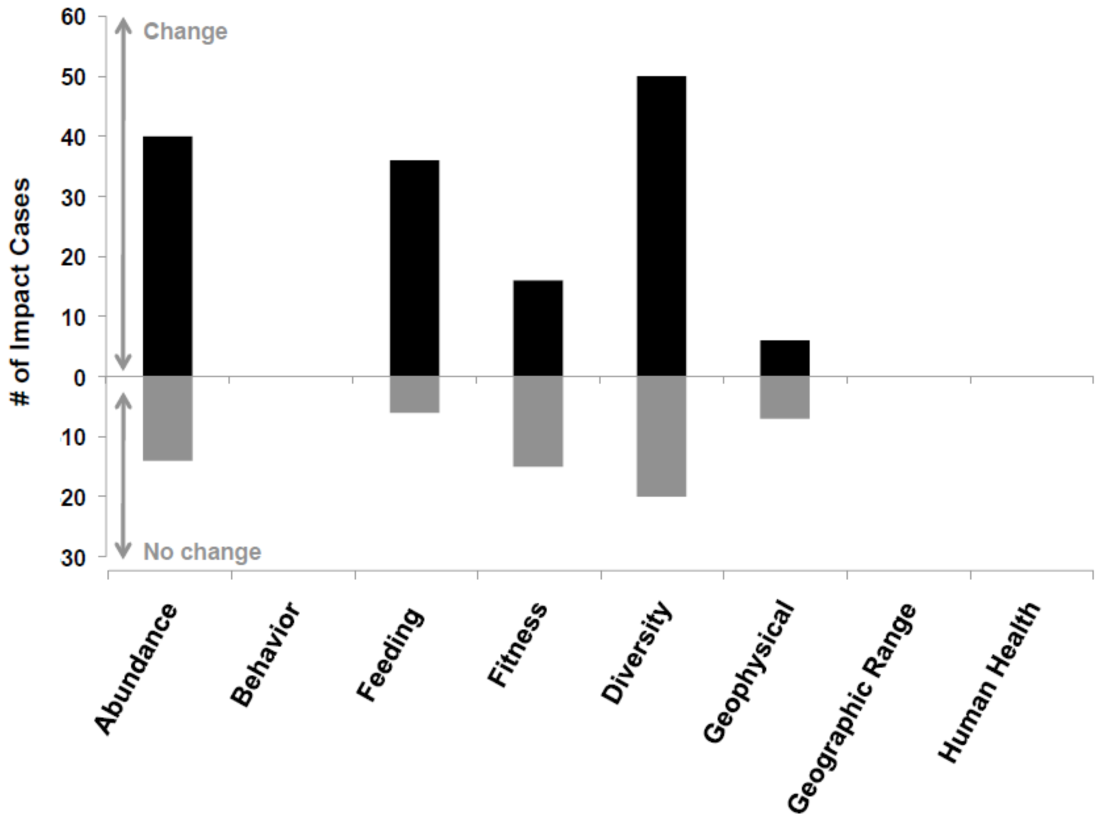

Figure 18. Summary of number of cases reported in the literature searched in which the presence of non-native macroalgae species were associated with a change in a response variable. 'Change' includes a positive or negative difference in a response variable as well as responses that have no direction (upper black bars), such as a change in community structure vs. no impact (lower gray bars) on surrounding native communities or environments. See Appendix V for an explanation of data set and impact categories.

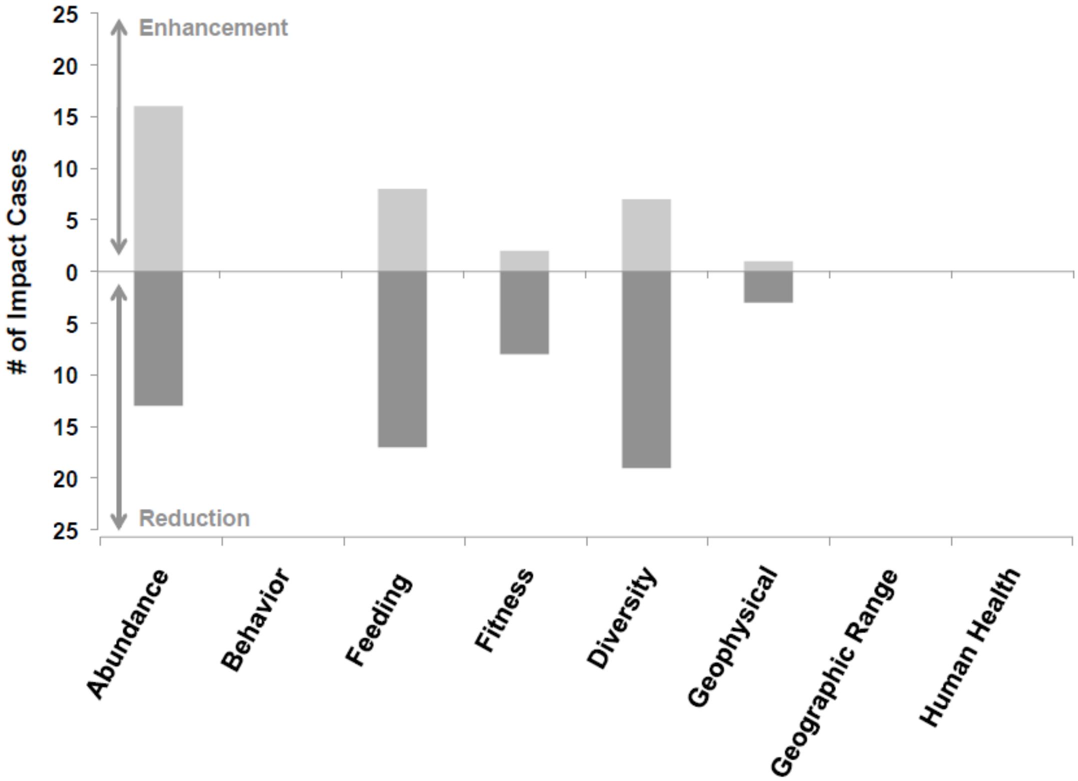

Figure 19. The number of studies (cases) for macroalge introduced by aquaculture that show either a significant positive impact (‘Enhancement’, upper black bars) vs. negative impact (‘Reduction’, lower gray bars) on surrounding native communities. See Appendix V for an explanation of data sets and impact categories.

4.0 Discussion and Recommendations

Our data show that aquaculture continues to pose a low but significant risk of introducing NIS into California. Historically, many species were introduced unintentionally as hitchhikers with aquaculture shipments particularly with oysters (Miller et al. 2007). Although longer term trends show that the number of species that are being brought into the state has declined over the past several decades, these same data indicate that increasingly larger numbers of those few NIS species are being imported from outside the state. More than 80% of the species likely associated with aquaculture and nearly 50% of species imported solely associated with aquaculture have become established somewhere in California. Therefore, species associated with aquaculture come with a high likelihood of establishment.

The distribution of established species, either total or first records, is disproportionately into bays and estuaries where aquaculture has historically or continues to take place. The vast majority of these species have been introduced initially into northern California sites. This is mirrored by the destination of permitted species being primarily into northern California sites such as Humboldt Bay and Tomales Bay. The source of these permits and therefore, the source of the species into California is primarily from the western U.S. including Hawaii, Washington and Oregon.

What was most surprising was how little information is available regarding the movement of NIS into California via aquaculture. Because of gaps in regulations and reporting, we don't really have any reasonable estimate of the quantity of various NIS coming into the state via this vector, and in some cases there is uncertainty about the species itself. This is particularly unfortunate because of the high likelihood of establishment for aquaculture species. These are generally large, hardy species that are typically brought because of their likelihood of surviving local conditions. Although the life stages imported under current practices are small stages such as larvae or small juveniles, as they develop into market size adults, they increasingly pose a risk of becoming established.

Given this lack of information on aquaculture introductions, we make the following recommendations for improving the acquisition of information that we believe is necessary to more accurately evaluate the strength of aquaculture and hence the risk of aquaculture as a vector for NIS currently and in the future.

Recommendations for Permitting and Reporting

As a result of the data collection associated with this project, it has become clear that there are insufficient details reported to develop a complete picture of aquaculture in the state. Among the unanticipated data gaps is the lack of information on propagule supply. We initially expected to be able to determine the number or volume of at least oysters being planted over time and within specific areas, but permits do not require or specify this information. To facilitate a better understanding of what is actually occurring, the following amendments to reporting mechanisms are suggested. For import permits, there needs to be a required submission of an import activity report as well. Because import permits only regulate whether a species can be brought into the state from a particular origin, they do not report on the actual import activities undertaken. It would be beneficial if upon completion of the permitted time period, importers were required to file an activity report that included volume imported from each origin. Requiring the reporting of volume on import permits would allow for the estimation of flux for incoming volume of species. This is currently not calculable from the import permit. Additionally, it would be useful to standardize the required details on the imported organisms within this report. These details should include the organism's scientific name, ploidy (diploid vs. triploid), and life stage. This activity report would be parallel to the Proof of Use Report required to detail the actual aquaculture activities undertaken. Requiring the reporting of activity in addition to obtaining a permit would also be similar to the new requirement that in addition to obtaining a restricted species permit, permittees must report the actual acquisition or loss (either through death or sale) of restricted species. Proof of Use Reports should also be standardized so that equivalent information is provided by all growers. This information should include origin of seed stock (this would provide a better estimate of in-state versus out-of-state seed origins), species scientific names, and ploidy.

Another recommendation that would both simplify and improve compliance with permitting and reporting would be the development a process that would provide a single permit application for aquaculture businesses that would be reviewed and recognized by multiple state and federal agencies. A possible model for this is the Joint Aquatic Resources Permit Application (JARPA) that is available in California for a wide range of activities affecting the coastal zone. Many agencies participate including CDFG, USFWS, USACE and others and covers a number of regulations including Porter-Cologne, CERES, CEQA, the California Coastal Act and others. The complexity and uncertainty of enforcement in the current permitting procedures clearly indicates that there is strong need to streamline and simplify the aquaculture permitting process as well as the subsequent reporting process.

A major advantage of this approach using a single permit application would be to centralize all the information for permitting, rules, regulations, etc. This would also facilitate a centralized platform for aquaculture information and provide a "one stop shop" bringing together and making available all the aquaculture data statewide. This would be an important step in addressing the data gaps we have uncovered in these reports.

Aquaculture Industry and Trade Groups

There are several industry-related groups that represent aquaculture business. One is the California Aquaculture Association (http://www.caaquaculture.org/) with is largely comprised aquaculture industry representatives who coordinate with agency and university members among others. There is also the Pacific Coast Shellfish Growers Association (http://www.pcsga.net/) whose board is comprised solely of representatives from shellfish growers from California, Oregon, Washington and Alaska. Both of these groups promote appropriate stewardship and sustainable production of aquaculture products. However, limiting the risk of future introductions, while acknowledged as a goal by many producers, would be better achieved if this was a higher priority for these groups. Other groups include the Pacific States Marine Fisheries Commission (http://www.psmfc.org/), a non-governmental organization with substantial agency and industry participation that promotes fishery resources from California to Alaska. This organization has actively promoted an aquatic invasive species prevention program that has supported many efforts to limit the establishment and spread of marine and estuarine invasions.

We recommend that industry and trade groups like these would work to develop and maintain best management practices in order to limit the likelihood of spread and establishment of non-native hitchhiker species. These can include pathogens and parasites as well as attached or fouling species and would include both aquaculture material and associated structures (shells, bags, ropes, etc.) (Mineur et al. 2007). We recommend the guidelines developed by ICES in order to minimize subsequent spread and establishment (ICES 2006, also see NRC 2010).

The current industry practices represent a very low risk of introducing hitchhiker species (unintentional introductions). Most shellfish (oysters, clams, mussels) come into California via shipments with the organisms kept moist without any significant volume of water that might contain hitch hikers. Species such as the Pacific oyster typically are transported as 'cultch-less seed' as individual oysters on tiny pieces of shell, although there is still a significant volume of seed-on-cultch, although with very small (<1 mm) oysters shipped directly from hatchery tanks. Pacific oysters are also shipped as larvae and kept 'damp' in balls of moist sand.

We do note that despite present industry practices that have dramatically reduced the risk of introducing hitch hikers relative to past decades, there have still been eight species introductions since 2000 where aquaculture is a possible vector. However, we cannot definitively distinguish between species actually introduced after 2000 from those that were introduced prior to 2000, but only discovered after 2000. These introductions do include three species where aquaculture is listed by NEMESIS as the sole vector for introduction; all three are digenetic trematode parasites. Therefore, vertebrate hosts such as birds remain a possible vector as well.

While the industry has made significant efforts to reduce the likelihood introductions via hitchhiking, under current regulations, this is still a possibility if in the future shipments were imported differently than under current practices. Although CDFG has authority to inspect shipments that would contain significant amounts of associated water under Title 14 Section 236 (see sections c2-5 in Appendix VII), the current industry practices where organisms are at very small stages are shipped 'damp', are largely voluntary. Industry practices are thus subject to change in the future.

The other aspect of the risk posed by aquaculture is that associated with likelihood of introduction of the target species for aquaculture. Although few intentionally introduced species have become established and spread with significant impacts, there continues to be the possibility of this occurring. The most obvious species where this risk is high is the commercially grown Pacific oyster *Crassostrea gigas,* where established populations have been tentatively identified in more than one location in CA (see Box 2). Therefore, part of the risk posed by aquaculture also involves the risk of the spread and establishment of species intentionally brought into CA for culture in the waters of the state.

Aquaculture itself also provides additional hard substrate which may support high impact species like ascidians (tunicates), which can rapidly foul boats, docks, pilings as well as aquaculture facilities themselves (Tyrrell and Byers 2007). Ascidian species tend to be highly invasive worldwide (Bullard et al. 2007, Denny 2008) and are associated with aquaculture structures that provide hard substratum in otherwise soft sediment environments such as seagrass beds, which are protected wetland species under the Clean Water Act (Williams 2007). Ascidians foul bivalve product and non-native ascidians comprise a significant proportion of ascidian foulers (Rodriguez and Ibarra-Obando 2008). The identification of *Didemnum vexillum* in Tomales Bay has been attributed to aquaculture structures and is present on oysters cultured in Drakes Estero. This ascidian is highly invasive and has shown its ability to colonize not only hard substrata but also eelgrass (Glasby 2000, Bullard et al. 2007, Carmen and Grunden 2010, Grosholz, unpubl. data). Non-native ascidians also survive and grow faster than native ascidians in warmer waters in California, a characteristic that should favor their spread in the future (Sorte et al. 2010).

Box 4. Reducing Introduction Risk with Triploids. The majority of Pacific oysters *C. gigas* introduced into California for aquaculture have been diploids. The industry has available triploids that were developed for aquaculture as sterile alternatives to diploids. Among our suggested recommendations would be to encourage greater use of these triploid stocks where possible. Triploid oysters in most cases possess the same market qualities as the naturally occurring diploids, but the extra gene copies render these incapable of reproducing barring reversion to diploid (which may occur at low frequency). This has been required for the importation of other non-native oysters such as *Crassostrea ariakensis* imported and grown in the Chesapeake Bay. In the case of the Pacific Oyster in California, the introduction status is unknown (see Box 2). However, the risk of additional establishment and spread of Pacific oysters would be reduced with increased use of triploid individuals. We strongly encourage the industry to adopt standards that would encourage the use of triploid oysters.

Other Factors Affecting Introduction, Establishment and Spread

Once a species been successfully introduced via a particular vector like aquaculture, a variety of factors may ultimately determine whether that species becomes established, spreads to other sites and exerts a significant ecological or economic impact. The full list of factors influencing establishment, spread and impact is extensive and there is both a well-developed theoretical literature as well as many empirical test of factors influencing each of these steps in the invasion process. Even a minor discussion of these factors is far beyond the scope of this report (see NAS 2010 Chapter 2 for a detailed discussion).

The likelihood of establishment can be function of not only the number of propagules introduced by a given vector like aquaculture, but several other factors that determine ‘propagule pressure’ (Williamson 1996, Lonsdale 1999). Propagule pressure can include the degree of environmental matching between the origin of the propagules and the recipient community, the life stage of propagules, specific traits of the organism, genetic diversity of propagules, in addition to the number of propagules introduced.

In the context of the aquaculture vector, historically the propagules included adult stages of targeted aquaculture species. Currently, these almost exclusively include larval or juvenile stages of species such as oysters, mussels, clams, etc. Repeated introductions may increase the likelihood of establishment. For hitchhiking species, a broader range of life stages may be introduced although little is known about how this might affect establishment.

The subsequent spread of species intentionally or unintentionally introduced by aquaculture is typically no different than for species introduced by other vectors. Aquaculture hitchhikers may be spread accidentally by the movement of aquaculture field gear including racks, cages, floats, etc. Efforts to reduce the cover of fouling species on gear and avoiding the transport of fouled gear between bays is a typical practice of the aquaculture industry.

Potential Future Trends

The future is one of increasing reliance on aquaculture to fulfill the nutritional needs of a growing world population. In the U.S., two-thirds of marine aquaculture production is comprised of bivalve molluscs, and NOAA, which will largely dictate federal aquaculture investments, is looking to expand aquaculture production over the next decade (http://www.nmfs.noaa.gov/aquaculture/aquaculture_in_us.html). Most of this production will involve native species as it currently does, however in California, oyster and mussel culture is primarily non-native species. The degree to which aquaculture in California will involve the continuing or even expanded importation and production of non-native species is uncertain.

Relative to the historic period where nearly entire oyster reefs were transferred from Atlantic collections sites to San Francisco Bay, current industry and agency inspection standards have dramatically reduced the risk of introduction for species associated with aquaculture including hitchhiking fouling species, pathogens, etc. Therefore, the risk of introducing associated species is relatively small, although clearly this risk is not zero as the introduction of the abalone shell parasite makes clear.

The results of this study suggest that there are ongoing significant risks associated with the continued importation of NIS for aquaculture (Ruesink et al. 2005). The impacts of oyster species that are not established in California such as *Crassostrea gigas* can potentially be significant. Following introduction of *Crassostrea gigas* into Australia and New Zealand (not native in either), there were dramatic declines in abundances of the native rock oyster *S. glomerata* in both countries (NAS 2003). There is the potential for *C. gigas* to have similarly negative impacts on the native Olympia oysters and other native species should it become established in California waters. The aquaculture industry has made efforts in the past to avoid this through the use of infertile triploid oysters, although there is a small risk of reversion to diploidy and fertility (Zhang et al. 2010). Nonetheless, this trend of using triploids where possible should be continued in the future with more efforts aimed at importing reproductively infertile individuals for aquaculture.

Role for Education

As for almost every issue, there exists a positive role for greater public awareness through education and outreach. Despite a broad range of efforts to educate the public about the risks as well as the economic invasive species, the public generally has a limited role and influence on aquaculture as a vector. Obviously the same general education programs that provide the public with guidelines about not moving species around, where to go and who to contact in case an unusual or unfamiliar species is found apply to any and all NIS. There are instances where private citizens have engaged in private unregulated aquaculture activities including *C. gigas* being grown on private property along a stretch of the San Francisco Bay shoreline (T. Moore, CDFG).

Also, many anecdotes exist of private citizens purchasing aquaculture products such as bags of oysters or clams and transporting them to other water bodies and 'hanging' the bags from docks or pilings. Public education in this case would certainly reduce the risk of after-sale transport of species, but again these risks are not associated with the industry and apply broadly to all NIS. There are many opportunities for continuing to work with industry and agency partners (see Pacific Shellfish Institute as an example http://www.pacshell.org/) to ensure that aquaculture proceeds in ways that will continue to reduce the risk of future introductions of NIS in California waters.

Coordination Across Vectors and Future Research Directions

In parallel with the reports on other vectors (Ornamental Trades, Fishing and Recreation Vessels and Live Bait and Seafood), a major goal for all AIS teams was to identify the gaps in understanding the vectors as pathways for non-indigenous marine species in California, to provide useful information for management, and to assess the feasibility of a cross-vector risk assessment. To this end, the UCD team was responsible for coordinating efforts and results across vectors. Below we describe the collaborative approach among the teams, co-directed by OST, and progress toward cross-vector assessments.

Step 1- Conceptual Model for Risk of Invasions. We developed a consensus for a first-cut simple conceptual risk assessment model to be used to guide collection and analysis of data from the various vectors (see Objectives section).

Step 2- Impacts Database. We developed a coordinated approach to collecting data on impacts across vectors. We jointly developed an impact database that included ecological, human health, and economic impacts, to be populated by SERC (crustaceans) and UCD (seaweeds, molluscs) based on literature searches using identical search terms. We also developed an initial expert judgment survey template for future evaluation of impact because we uncovered a paucity of data. See Ornamental Trade Vector report for details of expert judgment survey template.

Step 3- Data Gaps and Vector Risk Comparisons. This step is to outline an approach to develop a more refined model for a cross-vector risk assessment. Development is an ongoing discussion by SERC, UCD, and OST. As mentioned in the Introduction and Objectives, a cross-vector risk assessment, even of the most qualitative manner, has not been achieved to our knowledge. The types of data we gathered have been used to inform single species invasion risk assessments in some marine ecosystems (Campbell 2009). *However, we know of no existing risk assessment approaches that characterize relative* *risks of multiple invasion vectors for multiple species.* There are other types of risk assessment techniques for evaluating relative invasion risk that might be scalable for multiple species and vectors (reviewed in Wonham and Lewis 2009). All of these approaches require significant amounts of data, which proved to be unavailable for most of California's non-indigenous marine species and the vectors delivering them.

The data collected by research teams funded by the Ocean Protection Council to assess six vectors for marine non-indigenous species in California should enable assignment of such species to vectors based on a combination of species trait information, year of first record, and timing of vector operation. Vector assignment will allow a first-cut relative comparison of the vectors to which introductions have been attributed and expand upon Foss et al. (2007). A similar comparison could be made based on the number of established species, to ascertain whether species in one or the other vector is more likely to succeed (simple ratio of established/introduced). At a minimum, this type of analysis can be used to recommend changes in policy and outline future research needs for a specific region (for example see Moser and Leffler 2009).

Because we relied solely on peer-reviewed published data to quantify the impacts of species in the aquaculture vector, as with other vectors, this severely restricts the species that can be assessed across the full conceptual risk model incorporating introduction, establishment, and impact. To increase the pool of assessable species, several protocols have been developed for generating semi-quantitative expert assessments based on focused literature reviews, surveys, and workshops that incorporate unpublished information about traits, distributions, and other factors (Orr et al. 1993, Hayes 2002, Hayes et al. 2002, NISC 2003, Orr 2003, ANSTF & NISC 2007, Therriault and Herborg 2008, Acosta and Forrest 2009). These approaches inform our efforts to develop a robust multi-species, multi-vector risk assessment process. See Ornamental Trade Vector report for additional discussion.

Summary Management Recommendations

- The current permitting process for aquaculture must be streamlined and centralized with a single permit for all aquaculture activities that would be recognized by all authorizing agencies.
- Greater detail of information must be included in this permitting process including accurate species identification and quantities or each imported, life stages and ploidy of the species, origin, and final destination
- A centralized, state-wide data base must be developed that integrates and makes available in one place all the data contained in the aquaculture permits
- California must engage in a quantitative cross-vector assessment for marine non-indigenous species
- Target aquaculture species such as Pacific oysters that are non-native and not yet established should be imported as triploids whenever possible
- Education programs must be developed and this information adequately disseminated that communicates the costs to the state of NIS and what is required to reduce the future risk of introductions

Summary Research Recommendations

- Establish standardized sampling of species and volumes circulating within the main vectors
- Use expert knowledge to develop a cross-vector risk assessment based on expert knowledge
- Investigate the cost and feasibility of 'white lists' and 'black lists' for non-indigenous aquaculture species
- Conduct comprehensive, annual surveys of non-indigenous marine species in California including coverage of critical habitats and MPAs
- Assess the ecological impacts of non-indigenous aquaculture species
- Conduct a comprehensive economic impact assessments of the aquarium trade

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6.0 Appendices

Appendix I. Non-native Species Associated With Aquaculture

The list of non-native species associated with aquaculture where aquaculture is either the sole or a possible vector reported from California including the year and location of first record for the state. In a few cases, indicated in the notes column, aquaculture was not considered a likely vector for the first state report, but was implicated in subsequent reports. Asterisks denote taxa of unknown (*) or failed/extinct (**) status. Species highlighted in yellow were intentionally introduced for aquaculture purposes; all others are unintentional introductions (=hitchhikers). Species highlighted in red are hitchhikers that have been introduced since 2000 when standardization of current aquaculture importation practices were completed.

Species	Taxonomic group	First Record	First Record	Intentional?	Sole/Multiple vectors
Abludomelita rylovae	Crustacea	San Francisco Bay	1993	no	multiple
Alitta succinea	Annelida	San Francisco Bay	1896	no	multiple
Ampelisca abdita	Crustacea	San Francisco Bay	1954	no	multiple
Amphibalanus albicostatus**	Crustacea	San Francisco Bay, Elkhorn Slough	1930	no	sole (ES), multiple (SF)
Amphibalanus improvises	Crustacea	Elkhorn Slough	1998	no	multiple
Ampithoe sp.*	Crustacea	San Francisco Bay	1994	no	multiple
Ampithoe valida	Crustacea	San Francisco Bay	1941	no	multiple
Anadara ovalis**	Mollusca	San Francisco Bay	1967	no	sole
Anadara transversa**	Mollusca	San Francisco Bay	1918	no	sole
Ancistrocoma pelseneeri	Protozoa	San Francisco Bay	1936	no	sole
Ancistrum cyclidioides	Protozoa	San Francisco Bay	1946	no	sole
Anomia simplex**	Mollusca	San Francisco Bay	1912	no	sole
Aoroides secunda	Crustacea	San Francisco Bay	2004	no	multiple
Argopecten irradians**	Mollusca	San Francisco Bay	1963	no	sole
Austrobilharzia variglandis	Platyhelminthes	San Francisco Bay	1954	no	sole
Barentsia benedeni	Entoprocta	San Francisco Bay	1929	no	multiple
Batillaria attramentaria	Mollusca	Tomales Bay	1941	no	sole
Bonamia ostreae*	Protozoa	Drakes Estero	1966	no	sole
Boonea bisuturalis	Mollusca	San Francisco Bay	1962	no	multiple
Botrylloides violaceus	Tunicata	San Francisco Bay	1973	no	multiple
Botryllus schlosseri	Tunicata	San Francisco Bay	1947	no	multiple
Botryllus sp. A.	Tunicata	San Francisco Bay	1983	no	multiple
Bugula neritina	Ectoprocta	Elkhorn Slough	1905	no	multiple
Bugula stolonifera	Ectoprocta	Humboldt Bay	2002	no	multiple
Busycotypus canaliculatus	Mollusca	San Francisco Bay	1938	no	multiple
Callinectes sapidus**	Crustacea	San Francisco Bay	1897	yes	sole
Caprella drepanochir	Crustacea	Humboldt Bay	2006	no	multiple
Caprella mutica	Crustacea	Humboldt Bay	1973	no	multiple

Caprella scaura	Crustacea	Elkhorn Slough	1978	no	multiple
Ceramium kondoi	Rhodophyta	Bodega Bay	1999	no	multiple
Cercaria batillariae	Platyhelminthes	Elkhorn Slough	1994	no	sole
Chalinula loosanoffi	Porifera	San Francisco Bay	1950	no	multiple
Ciona intestinalis	Porifera	San Francisco Bay	1932	no	multiple
Cladonema pacificum	Cnidaria	San Francisco Bay	1979	no	multiple
Clathria prolifera	Porifera	San Francisco Bay	1950	no	multiple
Clava multicornis*	Cnidaria	San Francisco Bay	1895	no	multiple
Cliona sp.	Porifera	San Francisco Bay	1891	no	sole
Codium fragile ssp .fragile	Chlorophyta	San Francisco Bay	1977	no	multiple
Conopeum tenuissimum	Ectoprocta	San Francisco Bay	1951	no	multiple
Corbicula fluminea	Mollusc	San Francisco Bay	1945	no	multiple
Cordylophora caspia	Cnidaria	San Francisco Bay	1930	no	multiple
Corymorpha sp. A	Cnidaria	San Francisco Bay	1955	no	multiple
Crassostrea gigas*	Mollusca	Tomales Bay	1928	yes	sole
Crassostrea virginica**	Mollusca	San Francisco Bay	1869	yes	sole
Crepidula convexa	Mollusca	San Francisco Bay	1898	no	sole
Crepidula fornicata**	Mollusca	Humboldt Bay	1935	no	sole
Crepidula plana	Mollusca	San Francisco Bay	1898	no	sole
Cryptosula pallasiana	Ectoprocta	San Francisco Bay	1943	no	multiple
Diadumene leucolena	Cnidaria	San Francisco Bay	1936	no	multiple
Diadumene lineata	Cnidaria	San Francisco Bay	1906	no	multiple
Didemnum vexillum	Tunicata	Elkhorn Slough	1998	no	multiple
Diplosoma listerianum	Tunicata	Bodega Bay	1980	no	multiple
Eriocheir sinensis	Crustacea	San Francisco Bay	1992	no	multiple
Eubranchus misakiensis	Mollusca	San Francisco Bay	1962	no	multiple
Eurytemora carolleeae	Crustacea	San Francisco Bay	1913	no	multiple
Eusarsiella zostericola	Crustacea	San Francisco Bay	1953	no	sole
Exopalaemon carinicauda*	Crustacea	San Francisco Bay	1993	no	multiple
Gelidium vagum	Rhodophyta	Tomales Bay	1996	no	sole
Gemma gemma	Mollusca	San Francisco Bay	1893	no	sole
Geukensia demissa	Mollusca	San Francisco Bay	1894	no	sole
Gigantobilharzia sp.	Platyhelminthes	San Francisco Bay	2005	no	multiple
Gnorimosphaeroma rayi	Crustacea	Tomales Bay	1952	no	sole
Gracilaria vermiculophylla	Rhodophyta	Elkhorn Slough	1994	no	multiple
Grandidierella japonica	Crustacea	San Francisco Bay	1996	no	multiple
Grateloupia lanceolata	Rhodophyta	Elkhorn Slough	2008	no	multiple
Halichondria bowerbanki	Porifera	San Francisco Bay	1950	no	multiple
Haminoea japonica	Mollusca	San Francisco Bay	2004	no	multiple
Haplosporidium nelsoni*	Protozoa	Drakes Estero	1990	no	sole
Heteromastus filiformis	Annelida	San Francisco Bay	1936	no	multiple
Himasthla quissetensis	Platyhelminthes	San Francisco Bay	2003	no	sole
Homarus americanus**	Crustacea	San Francisco Bay	1874	no	sole

Ilyanassa obsoleta	Mollusca	San Francisco Bay	1907	no	sole
Jassa marmorata	Crustacea	San Francisco Bay	1977	no	multiple
Lepocreadium setiferoides	Platyhelminthes	San Francisco Bay	2003	no	sole
Limnodriloides monothecus	Annelida	San Francisco Bay	1985	no	multiple
Littorina littorea**	Mollusca	Mad/Redwood River	1943	no	sole
Lomentaria hakodatensis	Rhodophyta	Humboldt Bay	1990	no	multiple
Macoma petalum	Mollusca	San Francisco Bay	1988	no	multiple
Melita nitida	Crustacea	San Francisco Bay	1938	no	multiple
Mercenaria mercenaria	Mollusca	San Francisco Bay	1901	yes	sole
Meretrix lusoria**	Mollusca	Humboldt Bay	1957	no	sole
Molgula manhattensis	Tunicata	Tomales Bay	1949	no	multiple
Monocorophium acherusicum	Crustacea	San Francisco Bay	1912	no	multiple
Monocorophium insidiosum	Crustacea	San Francisco Bay	1931	no	multiple
Monocorophiun uenoi	Crustacea	Morro Bay	1950	no	multiple
Musculista senhousia	Mollusca	Tomales Bay	1941	no	multiple
Mya arenaria	Mollusca	San Francisco Bay	1874	no	sole
Myosotella myosotis	Mollusca	San Francisco Bay	1871	no	multiple
Mytilicola orientalis	Crustacea	Tomales Bay	1962	no	multiple
Mytilus galloprovincialis	Mollusca	Multiple	1987	no	multiple
Nematostella vectensis	Crustacea	San Francisco Bay	1946	no	multiple
Nippoleucon hinumensis	Crustacea	Tomales Bay	2001	no	multiple
Nuttallia obscurata*	Mollusca	Elkhorn Slough	2005	no	multiple
Ocinebrellus inornatus	Mollusca	Tomales Bay	1941	no	sole
Okenia plana	Mollusca	San Francisco Bay	1960	no	multiple
Ostrea edulis**	Mollusca	Tomales Bay	1956	yes	sole
Ostrea puelchana**	Mollusca	San Francisco Bay	1962	yes	sole
Pacifastacus leniusculus	Crustacea	San Francisco Bay	1959	yes	sole
Petricolaria pholadiformis	Mollusca	San Francisco Bay	1927	no	multiple
Philine japonica	Mollusca	Tomales Bay	2004	no	multiple
Philine orientalis	Mollusca	Bodega Bay	1993	no	multiple
Procambarus clarkii	Crustacea	San Francisco Bay	1966	no	multiple
Prosuberites sp.	Porifera	San Francisco Bay	2004	no	multiple
Protodactylina pamelae	Crustacea	San Francisco Bay	1982	no	multiple
Pseudodiaptomus marinus	Crustacea	Mission Bay	1986	no	multiple
Rhithropanopeus harrisii	Crustacea	San Francisco Bay	1937	no	multiple
Sabaco elongatus	Annelida	San Francisco Bay	1960	no	multiple
Sakuraeolis enosimensis	Mollusca	San Francisco Bay	1972	no	multiple
Sargassum muticum	Phaeophyta	Smith River	1963	no	multiple
Schizoporella japonica	Ectoprocta	Elkhorn Slough	1952	no	multiple
Sinelobus cf. stanfordi	Crustacea	San Francisco Bay	1943	no	multiple
Sphenophrya dosiniae	Protozoa	San Francisco Bay	1946	no	sole
Spinileberis quadriaculeata	Crustacea	Tomales Bay	1970	no	sole
Stephanostomum tenue	Platyhelminthes	San Francisco Bay	2003	no	sole

Streblospio benedicti	Annelida	San Francisco Bay	1932	no	multiple
Styela clava	Tunicata	Elkhorn Slough	1935	no	multiple
Terebrasabella heterouncinata	Annelida	Central Coast	1996	no	sole
Trochammina hadai	Protozoa	Bodega Bay	1998	no	multiple
Tubificoides apectinatus	Annelida	San Francisco Bay	1961	no	multiple
Tubificoides brownae	Annelida	San Francisco Bay	1961	no	multiple
Tubificoides wasselli	Annelida	San Francisco Bay	1961	no	multiple
Upogebia affinis**	Crustacea	San Francisco Bay	1912	no	multiple
Urosalpinx cinerea	Mollusca	San Francisco Bay	1890	no	sole
Venerupis philippinarum	Mollusca	San Francisco Bay	1946	no	sole
Victorella pavida	Ectoprocta	San Francisco Bay	1967	no	multiple
Zoogonus lasius	Platyhelminthes	San Francisco Bay	N/A	no	sole

Appendix II. CDFG Long-Term Import Permit

Current long-term import permit used by CDFG from early 1990s to the present. This permit gives aquaculture businesses permission to import specified species from specified out of state growers for the 12- months from data of issuance.

State of California
The Resource Agency
DEPARTMENT OF FISH AND GAME
Marine Region
P.O. Box 1560
Bodega Bay, California 94923
(707) 875-4261

FOR DEPARTMENT USE ONLY

Permit Number: __________
Permit Term (no more than 12 months)
From: ________ To: ________
Fees Received: __________
Check Number: __________

LONG-TERM PERMIT TO IMPORT LIVE AQUATIC ANIMALS INTO CALIFORNIA

Authority and Reference: Section 236, Title 14, California Code of Regulations

Name of Importer: __________ Phone: ( )______

Mailing Address: __________
Street

____
City State Zip Code

Species to be Imported: __________

____

Source: __________ Phone: ( )______
Name

____
Street

____
City State Zip Code

Destination and Use: __________

____

____

____

Applicant's Signature: __________

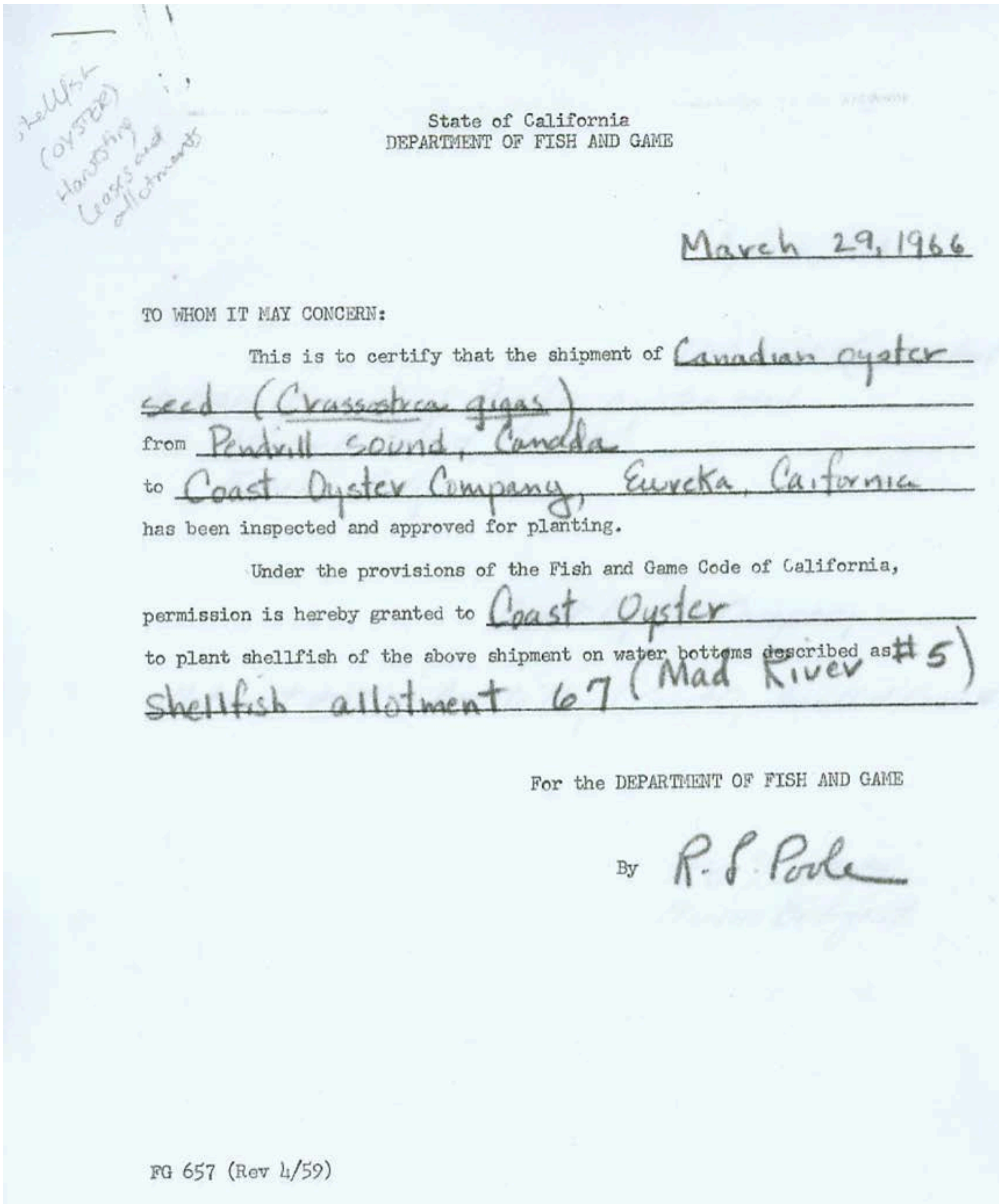
Approved By: __________ Issued By: __________
Marine Aquaculture Coordinator

Date Issued: __________

FG 786 (Revised 4/99)

Appendix III. CDFG Inspection and Planting Permit

Historical inspection and planting permit used by CDFG from 1960s to mid-1980s. This permit gave an aquaculture business permission to import specified species from specified out of state growers for a one-time import.



Shellfish (oyster) harvesting leases and allotments

State of California
DEPARTMENT OF FISH AND GAME

March 29, 1966

TO WHOM IT MAY CONCERN:

This is to certify that the shipment of Canadian oyster seed (Crassostrea gigas)
from Pendrell Sound, Canada
to Coast Oyster Company, Eureka, California
has been inspected and approved for planting.

Under the provisions of the Fish and Game Code of California, permission is hereby granted to Coast Oyster
to plant shellfish of the above shipment on water bottoms described as #5 (Mad River) shellfish allotment 67

For the DEPARTMENT OF FISH AND GAME

By R. S. Poole

FG 657 (Rev 4/59)

Appendix IV. CDFG Aquaculture Registration Application

Current Aquaculture Registration application used by CDFG from late 1980s to the present. All aquaculture facilities within the state of California are required to register with CDFG yearly.

California Natural Resources Agency
DEPARTMENT OF FISH AND GAME

2012 AQUACULTURE REGISTRATION APPLICATION

VALID JANUARY 1, 2012 THROUGH DECEMBER 31, 2012

(If issued after January 1, valid on date issued. *Includes $7.50 license buyer surcharge)

- ☐ NEW - FEE $736.00* ☐ NEW - ADDITIONAL FACILITY (NO FEE)
- ☐ RENEWAL - FEE $372.25* + $554.25* SURCHARGE FEE IF APPLICABLE
- ☐ RENEWAL - ADDITIONAL FACILITY (NO FEE)
- ☐ CHECK HERE IF MAILING OR FACILITY ADDRESS CHANGED

DFG USE ONLY
REGISTRATION NUMBER

SEE INSTRUCTIONS ON REVERSE. TYPE OR PRINT CLEARLY.

OWNER'S FIRST NAME	M.I.	LAST NAME	GO ID NUMBER (FROM ALDS ISSUED LICENSE)
BUSINESS NAME		FACILITY NAME *(If different from business name)*	DATE OF BIRTH
BUSINESS MAILING ADDRESS		BUSINESS TELEPHONE ( )	STATE LEASE NUMBER
CITY	STATE	ZIP CODE	COUNTY	E-MAIL ADDRESS *(Voluntary)*
FACILITY ADDRESS/LOCATION		CITY	STATE	ZIP CODE

ATTENTION APPLICANTS ☐ Check here if you wish the Department to include your business name, business address, and business telephone number on the list of aquaculturists released to the public.

BUSINESS CONDUCTED AT YOUR FACILITY *(Circle the letter for each type.)*

A - REARS TROUT FOR SALE	E - ALLOWS TROUT FISHING BY CUSTOMERS	I - REARS INVERTEBRATES FOR SALE	M - REARS SALMON/STEELHEAD FOR SALE
B - REARS WARM WATER FISH FOR SALE	F - ALLOWS WARM WATER FISHING BY CUSTOMERS	J - RESEARCH AND DEVELOPMENT	N - LIVE HAULER
C - REARS MINNOWS FOR SALE	G - ALLOWS TAKING OF FROGS BY CUSTOMERS	K - CONSULTANT	O - PROCESSOR
D - REARS FROGS FOR SALE	H - PRIVATE: NON COMMERCIAL	L - REARS AQUATIC PLANTS	P - REARS MARINE FIN FISH FOR SALE

SPECIES REQUESTED: *(Check each species.)* *Hybrid bass is limited to the specific geographic areas defined in Sections 240(h), Title 14, of the CCR.

☐ Abalone, red *(Haliotis rufescens)*	☐ Clam, Pacific geoduck *(Panopea generosa)*	☐ Minnow, fathead *(Pimephales promelas)*	☐ Shrimp, fresh water prawn *(Macrobrachium spp.)*
☐ Abalone, green *(Haliotis fulgens)*	☐ Clam, Manila *(Venerupis japonica)*	☐ Minnow, goldfish *(Carassius auratus)*	☐ Shrimp, common white *(Litopenaeus setiferus)*
☐ Bass, smallmouth *(Micropterus dolomieu)*	☐ Crappie, black *(Pomoxis nigromaculatus)*	☐ Minnow, goldfish x carp hybrid *(all spp.)*	☐ Sturgeon, white *(Acipenser transmontanus)*
☐ Bass, striped *(Morone saxatilis)*	☐ Crappie, white *(Pomoxis annularis)*	☐ Minnow, golden shiner *(Notemigonus crysoleucas)*	☐ Sunfish, green *(Lepomis cyanellus)*
☐ Bass, (hybrids) *(Morone saxatilis)**	☐ Crayfish, signal *(Pacifastacus leniusculus)*	☐ Mosquitofish *(Gambusia spp.)*	☐ Sunfish, redear *(Lepomis microlophus)*
specify strain ____________	☐ Crayfish, red swamp *(Procambarus clarkii)*	☐ Mosquitofish, western *(Gambusia affinis)*	tilapia - specify species:
☐ Bass, largemouth *(Micropterus salmoides)*	☐ Croaker, orgmth corvina *(Cynoscion xanthulus)*	☐ Mussel, bay *(all spp.)*	☐ *(hornorum)* ☐ *(mossambica)*
☐ Bluegill *(Lepomis macrochirus)*	☐ Drum, red *(Sciaenops ocellatus)*	☐ Mussel, sea *(Anodonta spp.)*	☐ Trout, brook *(Salvelinus fontinalis)*
☐ Bullfrog *(Rana catesbeiana)*	☐ Halibut, California *(Paralichthys californicus)*	☐ Oyster, Pacific *(Crassostrea gigas)*	☐ Trout, brown *(Oncorhynchus trutta)*
☐ Cabezon *(Scorpaenichthys marmoratus)*	☐ Minnow, Sac blackfish *(Orthodon microlepidotus)*	☐ Oyster, Other ____________	☐ Trout, rainbow *(Oncorhynchus mykiss)*
☐ Catfish, brown bullhead *(Ameiurus nebulosus)*	☐ Minnow, carp *(Cyprinus carpio)*	☐ Perch, Sacramento *(Archoplites interruptus)*	
☐ Catfish, channel *(Ictalurus punctatus)*	☐ Minnow, koi carp *(Cyprinus carpio)*	☐ Scallop, rock *(Crassadoma gigantea)*	

OTHER SPECIES REQUESTED *(Please print clearly the common and genus and species names as shown above.)*

____

____

FOR FRESH WATER AQUACULTURE FACILITIES *(Complete the following information.)*

NEAREST TOWN	ROAD OR HIGHWAY	
TOWNSHIP	RANGE	SECTION

NAME AND DESCRIBE FULLY THE SOURCE FROM WHICH WATER IS OBTAINED AND THE LOCATION AND TYPE OF DIVERSION.

ON THE REVERSE SIDE, DRAW A MAP SHOWING ARRANGEMENT OF PONDS AND POINTS AT WHICH INLET AND OUTLET ARE SCREENED. IF YOU NEED MORE SPACE, ATTACH A SEPARATE SHEET.

FOR SALTWATER AQUACULTURE FACILITIES *(Provide cultivation area location information and indicate whether state-leased or private.)*

BAY OR AREA ______________________ LOT NUMBERS OR DESCRIPTION ______________________

FOR RENEWALS ONLY:

IF YOU MARK B BELOW, PLEASE INCLUDE PAYMENT OF THE REQUIRED SURCHARGE FEE IN ADDITION TO THE REGISTRATION FEE.

I certify under penalty of perjury that my total gross sales of aquaculture products during 2011 were: ☐ A. LESS THAN $25,000 ☐ B. AT LEAST $25,000

In the past year, have there been any changes to locations of premises, source of water, or screening of outlet or inlets of the ponds? ☐ YES ☐ NO

If you answered yes, describe the changes below:

I certify that I have read, understand, and agree to abide by, all conditions of this registration, the applicable provisions of the FGC, and the regulations promulgated thereto. I certify that I am not currently under any Fish and Game license or permit revocation or suspension, and that there are no other legal or administrative proceedings pending that would disqualify me from obtaining this registration. I agree that if I make any false statement as to any fact required as a prerequisite to the issuance of this registration, the registration is void and will be surrendered where purchased, and I understand that I may be subject to prosecution pursuant to FGC Section 1054 or to other administrative actions pursuant to Section 746, Title 14, of the CCR.

SIGNATURE **X**	TITLE	DATE

FOR DEPARTMENT OF FISH AND GAME USE ONLY

FACILITY INSPECTED/APPROVED BY	DATE	REGION	LRB ROUTED TO: ☐ FPB ☐ MRD ☐ REGION	ROUTED BY/DATE
REVIEWED BY/DATE	TRANSACTION #	LATE FEE ☐ $67.47	TRANSACTION #	ISSUED BY/DATE

NEW APPLICANTS MUST INCLUDE A COPY OF YOUR IDENTIFICATION WITH THIS APPLICATION

FG 750 (Rev. 10/11)

Appendix V. Definitions and Categories of Impact Data

Explanation of data sets used to for analysis of impacts for Mollusc and Algal species shown in Figures 16-19.

MOLLUCS TAXA

- Total # of Aqua species investigated through lit search = 38 (see Table 9 in Aqua report)
- Total # of Aqua species with at least 1 mensurative or experimental impact study (or case) = 9 out of 38 species
    - Names of species with impact studies = *Batillaria attramentaria, Crassostrea gigas, Crepidula fornicata, Littorina littorea, Ilyanassa obsoleta , Musculista senhousia, Mytilus galloprovincialis, Venerupis philippinarum, Myosotella myosotis*

-Total # of impact papers for these 9 species included in the following graphs = 61

- Total # of impact studies (or cases) within these papers included in the following graphs = 122

-Total # of impact papers conducted in California included in the following graphs = 8 of 61

ALGAE TAXA

- Total # of Aqua species investigated through lit search = 8 (see Table 9 in Aqua report)
- Total # of Aqua species with at least 1 mensurative or experimental impact study (or case) = 3 out of 8 species
    - Names of species with impact studies = *Codium fragile ssp fragile, Gracilaria vermiculophylla, Sargassum muticum*

-Total # of impact papers for these 3 species included in the following graphs = 49

- Total # of impact studies (or cases) within these papers included in the following graphs = 210

-Total # of impact papers conducted in California included in the following graphs = 0 of 49

GENERAL IMPACT CATEGORY	EXAMPLES of Response Variables
Abundance	density, % cover, biomass, settlement, recruitment
Behavior	burial depth, burrowing, foraging, habitat preference
Feeding	feeding preference, consumption rates, predation, absorption, fecal quality
Fitness	growth, reproduction, survival
Diversity	richness, evenness, community structure, assemblages, composition
Geophysical	filtration, nutrient cycling, erosion, flow rates
Geographic Range	geographic range
Human Health	human health, economic

Appendix VI. List of Acronyms for All Reports

AB – Assembly Bill
AIS – Aquatic Invasive Species
ANSTF – Federal Aquatic Nuisance Species Task Force
APHIS – Animal & Plant Health Inspection Service (USDA)
BIOSIS – Biosciences Information Service
CA – California
CDFA – California Department of Food & Agriculture
CDFG – California Department of Fish & Game
CEQI – Coastal Environmental Quality Initiative
CITES – Convention on International Trade in Endangered Species
FG – Fish & Game Permit (CDFG)
ISCC – Invasive Species Council of California
JFK – John F. Kennedy International Airport
JARPA – Joint Aquatic Resource Permit Application
LA – Los Angeles
LAX – Los Angeles International Airport
LEMIS – Law Enforcement Management Information System (USFWS)
MAC – Marine Aquarium Council
MIA – Miami International Airport
NEMESIS – National Exotic Marine and Estuarine Species Information System
NIS – Non-native Invasive Species
NISC – National Invasive Species Council
NOAA – National Oceanic and Atmospheric Administration
NWP – Nationwide Permit (USACE)
OST – Ocean Science Trust
PIJAC – Pet Industry Joint Advisory Council
POU – Proof of Use Reports (CDFG)
PPQ – Plant Protection & Quarantine (APHIS, USDA)
SAT – Science Advisory Team
SCBD - Secretariat of the Convention on Biological Diversity
SERC – Smithsonian Environmental Research Center
SF – San Francisco
SFO – San Francisco International Airport
UC – University of California
UCD – University of California, Davis
USACE – United States Army Corps of Engineers
USDA – United States Department of Agriculture
USWFS – United States Fish & Wildlife Service
WoRMS – World Register of Marine Species

Appendix VII. CDFG Regulations-Title 14 Section 236

This section of the California Code of Regulations includes CDFG Title 14 Section 236 which addresses the authority of CDFG to inspect shipments and to define which species can be lawfully imported in California without and importation permit.

14 CCR § 236
Cal. Admin. Code tit. 14, § 236

Barclays Official California Code of Regulations Currentness
Title 14. Natural Resources
Division 1. Fish and Game Commission-Department of Fish and Game
Subdivision 1. Fish, Amphibians and Reptiles
Chapter 9. Aquaculture (Refs & Annos)
§ 236. Importation of Live Aquatic Plants and Animals.

The provisions of this section shall apply to the importation of all live aquatic plants and animals.

(a) No person shall import into this state any prohibited species of live aquatic plant or animal listed pursuant to Section 2118 of the Fish and Game Code or Section 671 of these regulations unless specifically authorized by the commission.

(b) Unless specifically prohibited by these regulations, plants and animals within the following groups may be imported without an importation permit from the department:

(1) Mollusks and crustaceans intended to go directly into the seafood market and which will not be placed into the waters of the state nor placed in waters which are discharged to waters of the state.

(2) Live ornamental tropical marine or freshwater plants or animals that are not utilized for human consumption or bait purposes, are maintained in closed systems for personal, pet industry or hobby purposes, and which will not be placed in waters of the state.

(3) Brine shrimp.

(c) With the exception of those importations described in Section 236(a) and (b), live aquatic plants and animals may be imported into this state only in accordance with the following terms and conditions:

(1) A standard importation permit signed by the director or his agent is required, and no shipment into the state may be made prior to the issuance of the permit authorizing the shipment or shipments. The department shall charge a fee of $25.00 for issuing each permit. Fees charged for inspections shall be independent of the fees charged for issuing permits.

(2) With the exceptions of the live aquatic animals listed in subsection 236(c)(6), a permit is required for each lot or load, and each shipment must be accompanied by the original copy of the importation permit. Unless otherwise authorized, the person who is to receive any shipments of aquatic plants and animals shall apply to the department for this importation permit.

(3) Application for a standard importation permit shall be made on a form (Application for Standard Importation Permit, FG 789 (2/91), which is incorporated by reference herein) supplied by the department, as directed in Section 235(d) and shall reach the department's headquarters office at least 10 working days in advance of the probable arrival date of the shipment. A copy of the permit authorized by the director or his agent must accompany each load. If a change in date of shipment becomes necessary after a permit has been issued, the permittee shall notify the Aquaculture Development Section at least 5 days before the new date of shipment. Under special circumstances, the department may waive this 5-day notice requirement.

(4) All live aquatic plants and animals imported into California may be inspected by the department, either at the place of entry into the state or at other locations suitable to the department. The person importing the aquatic plants or animals may be required to provide facilities for inspecting and sorting them, and may be required to pay inspection costs, including salary and travel expenses of the inspector.

(5) Any lot or load of aquatic plants and animals found by the inspector to be diseased, parasitized or to contain species not authorized by the importation permit must be immediately destroyed or transported out of California within a period of time specified by the department. In such cases, the importation permit is automatically revoked.

(6) In lieu of the permits specified in subsection 236(c)(1), long-term permits for the following aquatic animals may be issued by the department for periods of up to one year. Application shall be made on a form (Application for Long-term Permit to Import Animals into California, FG 786 (2/91), which is incorporated by reference herein) supplied by the department. The department shall charge a fee for issuing each permit. See subsection 699(b) of these regulations for the fee for this permit.

(A) Oyster, oyster larvae and oyster seed.

(B) Ghost shrimps (Callianassa spp).

(C) Mud shrimps (Upogebia spp).

(D) Longjaw mudsuckers (Gillichthys mirabilis).

(E) Red swamp crayfish (Procambarus clarkii).

(F) Orconectes virilis.

(G) Marine Annelid worms (Phylum Annelida).

(H) Sacramento blackfish (Orthodon microlepidotus).

(I) Other species under conditions which the department determines represent no significant risk to the fish and wildlife resources of the state.

(7) Importation of Salmonid Eggs. Applications to import eggs of fishes of the family salmonidae (trout, salmon and char) shall be accompanied by a health certificate signed by a person competent in the diagnosis of fish diseases stating that the hatchery or other sources of the eggs to be imported and the eggs themselves are free of the following diseases: infectious pancreatic necrosis (IPN); bacterial kidney disease (BKD); infectious hematopoietic necrosis (IHN); and viral hemorrhagic septicemia (Egtved).

In questionable cases, the director of the department shall determine whether or not the person making the certification is technically qualified to do so.

(8) Only those aquatic plants and animals lawfully obtained in another state or country may be imported.

Note: Authority cited: Sections 1050, 2118, 6401, 15004, 15600 and 15601, Fish and Game Code. Reference: Sections 2116-2191, 2270-2272 and 3201-3204, Fish and Game Code.