Oil platforms off California are among the most productive marine fish habitats globally

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Edited by David W. Schindler, University of Alberta, Edmonton, Canada, and approved September 22, 2014 (received for review June 20, 2014)

Secondary (i.e., heterotrophic or animal) production is a main pathway of energy flow through an ecosystem as it makes energy available to consumers, including humans. Its estimation can play a valuable role in the examination of linkages between ecosystem functions and services. We found that oil and gas platforms off the coast of California have the highest secondary fish production per unit area of seafloor of any marine habitat that has been studied, about an order of magnitude higher than fish communities from other marine ecosystems. Most previous estimates have come from estuarine environments, generally regarded as one of the most productive ecosystems globally. High rates of fish production on these platforms ultimately result from high levels of recruitment and the subsequent growth of primarily rockfish (genus *Sebastes*) larvae and pelagic juveniles to the substantial amount of complex hardscape habitat created by the platform structure distributed throughout the water column. The platforms have a high ratio of structural surface area to seafloor surface area, resulting in large amounts of habitat for juvenile and adult demersal fishes over a relatively small footprint of seafloor. Understanding the biological implications of these structures will inform policy related to the decommissioning of existing (e.g., oil and gas platforms) and implementation of emerging (e.g., wind, marine hydrokinetic) energy technologies.

secondary production | ecosystem-based management | ecosystem services | energy technology | *Sebastes*

Secondary production is the sum of new biomass from growth for all individuals in a given area during a unit of time. Some of the original motivations for understanding biological productivity stem from the need to estimate the annual production of fishes that can be taken from a body of water (1, 2). By integrating multiple metrics that can individually reflect aspects of fitness (e.g., density, biomass, growth, fecundity, survivorship, body size, life span), secondary production can be thought of as a general criterion of success for a population (3, 4). Recent studies have extended this idea, using secondary fish production to provide a measure of the productive capacity and economic value of specific habitats within an ecosystem (5, 6) and, in a few instances, to evaluate the efficacy of creating artificial reefs and other forms of habitat restoration (7–9). In ecological studies, static properties such as density or biomass are typical structural response variables, whereas the use of secondary production, a functional measure, has been mostly limited to freshwater and marine benthic invertebrate studies (4). Meanwhile, marine ecologists and fisheries scientists continue to advocate for incorporating more ecosystem-based approaches to managing marine resources (10–12). This includes calls to add more elements of community and trophic ecology to the concept of essential fish habitat (12) and will likely involve the development of functional measures or indicators that incorporate several processes from within an ecosystem (13, 14).

The decommissioning of the >7,500 oil and gas platforms around the world (15, 16) is an unavoidable issue. Understanding the potential effects of the different decommissioning options on the biology of fishes living in such habitats will be important information to consider in the process. These options include "rigs-to-reefs" approaches where some portion of the platform is left in the water to continue functioning as an artificial reef. A main unresolved issue is the degree to which these types of structures enhance ecosystem function, and in particular secondary fish production, compared with nearby natural reefs (16–20). Additionally, with the current global emphasis on developing sources of renewable energy, deployment of new structures in the marine environment associated with offshore wind and wave energy extraction is increasing (21–23). These deployments may create opportunities to incorporate design elements that may enhance the conservation value and fisheries production associated with these structures.

Here, we compare the annual secondary production of fish communities on oil and gas platforms to those on natural reefs off the coast of southern California (Fig. 1) and to secondary production estimates of fish communities from other marine ecosystems. To calculate the annual secondary production for a fish community, referred to here as "Total Production," we develop a model based on fisheries-independent density and size structure data of fishes from visual surveys performed from a manned submersible once per year for between 5 and 15 y at each site. We define Total Production of the fish community as the sum of two components: "Somatic Production," which is the difference between the observed biomass during surveys and the biomass predicted 1 y later using species-specific morphometric, growth, and mortality functions, and "Recruitment Production," which estimates production from the growth of postlarval and pelagic juvenile fishes that settled or immigrated and survived during a 1-y time interval. Metrics for a "complete platform" were scaled to per square meter of seafloor, i.e., overall values were calculated for an entire platform, and then divided by the surface area of seafloor beneath the footprint of the platform. This permits a more direct comparison among platforms and natural

Significance

Secondary production is the formation of new animal biomass from growth for all individuals in a given area during some period of time. It can be a powerful tool for evaluating ecosystem function because it incorporates multiple characteristics of a population or community of organisms such as density, body size, growth, and survivorship into a single metric. Here, we find that fish communities living on the complex hardscape habitat created throughout the water column by the structure of oil and gas platforms off California have the highest secondary production per unit area of seafloor of any marine ecosystem for which similar estimates exist.

Author contributions: J.T.C., D.J.P., M.L., and A.S.B. designed research; J.T.C., D.J.P., M.L., L.A.Z., C.M.W., J.P.W., and A.S.B. performed research; J.T.C. and D.J.P. analyzed data; and J.T.C., D.J.P., M.L., L.A.Z., and A.S.B. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

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This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1411477111/-/DCSupplemental.

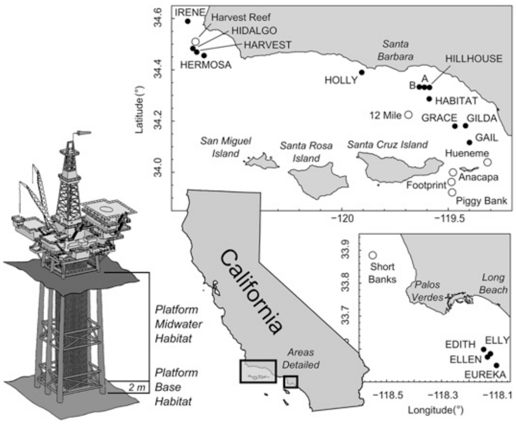

Fig. 1. Platform diagram and map of the study area. The platform midwater habitat encompasses the hard substrate of the platform structure from the water surface to 2 m above the seafloor, whereas the platform base habitat is the bottom 2 m of the platform structure. The platform structure consists of outer vertical pilings and horizontal crossbeams (i.e., the platform jacket) and the vertical oil and gas conductors in the center. Note this is a general display diagram and the designs of these structures vary from platform to platform. The 16 platforms (filled circles; names in all capital letters) and seven natural reefs (open circles) used in the study were surveyed for at least 5 (up to 15) y between 1995 and 2011.

reefs in the present study, and among estimates of secondary production of fishes in other ecosystems from the literature, which are also typically scaled to per square meter of seafloor (Table 1).

Results and Discussion

Oil and gas platforms off the coast of California have the highest secondary fish production per unit area of seafloor of any marine habitat that has been studied (Table 1). The mean annual Total Production per square meter of seafloor for complete platforms was significantly greater than, and 27.4 times as much as is produced per square meter on natural rocky reefs located at similar depths in the study region (Fig. 2*B* and Table S1). When platforms are evaluated individually, their average annual Total Production (range, 104.7–886.8 $\mathrm{g \cdot m^{-2} \cdot y^{-1}}$; Fig. 3) tended to be an order of magnitude higher than that of fish communities in other marine ecosystems where similar types of measurements have been made (range, 0.9–74.2 $\mathrm{g \cdot m^{-2} \cdot y^{-1}}$; Table 1). High rates of fish production per unit area of seafloor for the complete platforms are achieved because the platform jacket (horizontal crossbeams and vertical pilings) and oil and gas conductors create a complex structure that provides a large surface area of hard substrate throughout the water column (16, 19) (Fig. 1 and Table S2). This results in a high ratio of platform structural surface area to seafloor surface area (range, 5.4–20.2; Table S2), making large amounts of habitat available to juvenile and adult demersal fishes over a relatively small footprint of seafloor (range, 0.2–0.6 ha; Table S2). High structural complexity of hard substrate is often associated with marine habitats that have high abundance and diversity of fishes (24–26). The platform structure supports a diverse community of sessile and motile invertebrates that, along with planktonic food resources, provide the base of the food web for platform fishes (27).

Previous estimates of secondary production for marine fishes have come from more shallow habitats (Table 1). Most are from estuarine environments, generally regarded as one of the most productive ecosystems globally (28). Some estimates also come

Table 1. Estimates of secondary production of fishes from various marine ecosystems

Ecosystem	Fish production, $\mathrm{g \cdot m^{-2} \cdot y^{-1}}$	Reference
Oil platforms, California, United States	104.7–886.8*	Present study
Coral reef, Moorea	74.2*	Ref. 59
Estuary, Louisiana, United States	35.0–72.8*	Ref. 60 as cited in ref. 61
Coastal lagoon, (Pacific) Mexico	24.6–66.7*	Ref. 62 as cited in ref. 61
Artificial rocky reef, California, United States	66.5*[†,‡]	Ref. 8
Coastal lagoon, Texas, United States	12.1–57.6*	Ref. 63 as cited in ref. 61
Estuary, South Africa	55.9*	Ref. 61
Estuary, California, United States	37.6*[§]	Ref. 64
Coastal lagoon, Mexico	34.5*	Ref. 65
Salt marsh, New Jersey, United States	33.5[§,¶]	Ref. 66
Salt marsh, Delaware, United States	32.4[§,¶]	Ref. 67 recalculated in ref. 66
Coastal lagoon, Cuba	22.0–27.6*	Ref. 68 as cited in ref. 61
Deep rocky reef, California, United States	4.4–22.4*	Present study
Coastal lagoon, Mexico	20*	Ref. 69 as cited in ref. 61
Eelgrass bed, North Carolina, United States	18.4*[§]	Ref. 42
Estuary, Italy	9.0–17.0*	Ref. 70 as cited in ref. 61
Chesapeake Bay, United States	11.2–16.4*[†]	Ref. 71
Seagrass bed, southern Australia	2.7–15.8*[§]	Ref. 72
Coastal lagoon, Texas, United States	15.4*	Ref. 73
Mangrove habitat, Florida, United States	6.1–12.1[¶]	Ref. 74
Salt marsh, Massachusetts, United States	6.4[§,¶]	Ref. 75 recalculated in ref. 66
Soft bottom, California, United States	5.9*[†]	Ref. 8
Estuary, Scotland	4.3*	Ref. 76 as cited in ref. 61
Coastal lagoon, Portugal	0.9–2.5*	Ref. 77

After refs. 61 and 78. Also note that, although fish production of 29–901* $\mathrm{g \cdot m^{-2} \cdot y^{-1}}$ was reported for Bahamian tidal creeks, surveys were performed at low tide when fishes were aggregated into a fraction of the total available habitat. Therefore, the authors of that study caution against comparing these values with those from other studies (79).

*Based on summation of production estimates from multiple species in an assemblage.

[†] Original estimate for partial-year time interval was standardized to a 1-y interval.

[‡] Original estimate contained gonadal production component; only somatic production component is reported here.

[§] Original estimate was in grams dry weight and converted to grams wet weight by multiplying by 4 (64).

[¶] Production estimate for a single species.

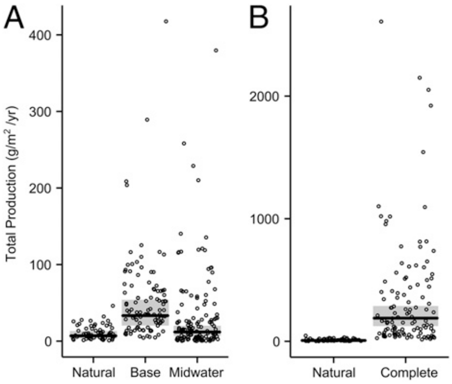

Fig. 2. Annual Total Production. (*A*) Annual production values scaled to per square meter of habitat for natural reefs (*n* = 56) and platform habitat subtypes [base (*n* = 111), midwater (*n* = 132)]. (*B*) Annual production values scaled to per square meter of seafloor for natural reefs (*n* = 56) and complete platforms (*n* = 111). Circles indicate individual data points and are jittered for visibility. Horizontal lines show the backtransformed estimated marginal means. The shaded box represents the 95% confidence intervals (CIs) of the mean. Differences were considered significant if the 95% CIs of their marginal means did not overlap.

from nearshore coral and rocky reefs, studies that typically account only for production of demersal fishes living near the surface of the habitat structure (see references in Table 1); thus, these studies do not account for production throughout the water column and may underestimate total production. These latter estimates may be more comparable to our estimates of production per square meter of transect along the two specific types of platform habitat: the "platform midwater habitat," which is the platform structure from the water surface to 2 m above the seafloor, and the "platform base habitat," which is the bottom 2 m of the platform structure (Fig. 1). When these estimates are compared, we still find some annual platform-specific estimates are well above the annual estimates from other ecosystems (see individual points >75 $g \cdot m^{-2} \cdot y^{-1}$ for base and midwater habitat in Fig. 2*A*; Table 1). Furthermore, the average annual amounts of production in those habitats for multiple different platforms (i.e., the sum of the two production components for individual platforms presented in Fig. S1) are also similar to or above secondary fish production estimates from the other ecosystems.

The high vertical relief platform midwater habitats of these structures are important nursery grounds for young rockfishes that settle to the platforms as larvae or pelagic juveniles (19, 29). Recruitment Production per square meter of midwater platform habitat (i.e., not scaled to per square meter of seafloor) was 3.7 times as much as that on natural reefs (Table S1). With hard substrate located throughout the water column, platform midwater habitat is likely more readily accessible than natural reefs to the settling fishes that tend to be found in the upper 100 m of the water column during their pelagic stage (30). Recruitment Production and Somatic Production of smaller fishes on platforms is likely further enhanced over natural reefs because predation rates on small fishes may be lower in platform midwater habitats (31), likely due to the relative scarcity of predators compared with natural rocky reefs in the region (19, 29). Increased habitat structure from artificial reefs in Florida has also been shown to reduce predation and increase production of demersal fishes (26). Ultimately, because the surface area of the structure on these California platforms is mostly midwater habitat (average, 96.8%; SE, 0.4%; range, 95.1–98.5%), platform midwater habitat tended to contribute much more than platform base habitat to the complete platform production metrics scaled to per square meter of seafloor (average contribution of platform midwater habitat: Somatic Production: 88.6%; SE, 3.7%; range, 57.7–99.0%; Recruitment Production: 94.9%; SE, 2.8%; range, 67.8–100.0%; Total Production contribution: 91.7%; SE, 2.8%; range, 69.0–99.5%).

As they grow older, rockfishes of many species tend to move into deeper waters (32), and this was evident in the patterns of fish production on the platforms. This ontogenetic habitat use pattern is also likely an important factor that may lead to the previously mentioned reduced predation on platforms, further separating juveniles and smaller adult fishes from the larger piscivorous fishes that may prey upon them. Significantly greater Total Production and Somatic Production values were observed per square meter of platform base habitat than in either natural reef or platform midwater habitat (Fig. 2*A* and Table S1). The Total Production and Somatic Production values of platform base habitat were 4.8 and 5.2 times as much as that on natural reefs, respectively. The structure at the bases of these platforms form complex "sheltering habitats" created by the large horizontal beams typically at or near the seafloor. They are often partially buried with fallen mussel shells and sediments further increasing the habitat complexity and creating preferred microhabitats for many species of adult rockfishes (33).

The classic "attraction–production debate," relating to constructing artificial reefs as a fisheries management tool to increase production of exploited fishes, centers primarily around whether hard-bottom habitat is a limiting factor. If so, additional habitat that produces fishes at an equivalent or better rate than natural habitats should result in increased production. However, if it is not limiting, then artificial habitat may only serve to attract and aggregate fishes, making them more easily caught, potentially resulting in further declines in overexploited fisheries (34, 35). Although platforms represent a small contribution to the overall hard substratum in California (18), these structures may be providing a large amount of the hard substrate below a depth of 50 m (17). Therefore, deeper-water platforms may provide considerable hard substrate in soft-bottom outer shelf regions (36). Furthermore, it is clear that juvenile rockfishes are recruiting to and being produced on platforms over multiple years, and these habitats may be valuable in rebuilding populations of bocaccio (*Sebastes paucispinis*), an overfished species in the region (29). A study modeling larval transport dynamics around one platform in this region also found that most juvenile bocaccio that did not recruit to the platform would otherwise have perished (37). Therefore, the platform was not drawing fish away from recruiting to other natural habitats, but providing a net increase in recruitment. This is likely not the case for all species and all platforms, and the isolation of platforms from extensive swaths of natural hard-bottom habitat possibly further contributes to their high rates

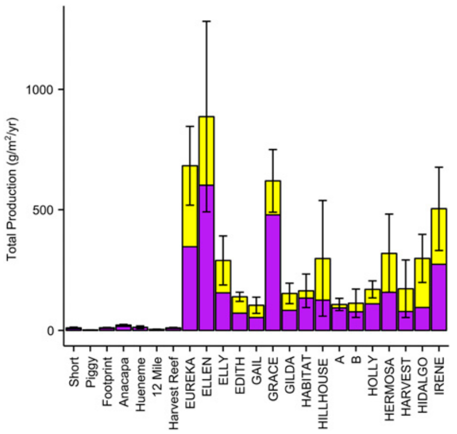

Fig. 3. Annual Total Production by site. Average of annual values scaled to per square meter of seafloor with SE error bars are divided into Somatic Production (purple) and Recruitment Production (yellow). Sites of each type are ordered from south to north, and platform site names are in capital letters. Note that the base habitat of platforms Habitat, Hillhouse, A, and B were never surveyed and therefore not included in these calculations, so their values will be underestimated.

of production. Production per square meter would likely be reduced if a platform was located adjacent to extensive areas of natural habitat. However, if survival rates of recruiting juveniles to platform midwater habitats were still enhanced over natural habitats, the platform would still act to increase the net production and possibly export adult fishes to surrounding habitats. Additionally, other authors suggest that if artificial structures are designated as no-take areas, then the attraction–production issue may cease to be relevant. This is because the main negative of attraction is that it may make it easier to exploit fishes, and thus protected reefs would only serve to export biomass through spillover and larval export (38). Many operational offshore structures associated with energy production, including some of the platforms in California, currently function as "de facto marine reserves" due to the difficulties of fishing them or safety regulations that limit fishing vessel access all together (22, 23, 39).

Relatively few taxa contributed more than 5% of the Total Production across all habitats (Table S3). This is a common pattern in other ecosystems, where the production of a fish assemblage is typically dominated by a few of the species (see references in Table 1). In all habitats studied here, the biggest contributors were various rockfish species (genus *Sebastes*) and lingcod (*Ophiodon elongatus*). Larger-bodied species such as lingcod and bocaccio, contributed more to production because they have relatively high growth and survival rates (Fig. S2) even though they were not the most abundant species. However, some smaller-bodied species, such as halfbanded rockfish (*S. semicinctus*) and squarespot rockfish (*S. hopkinsi*), also contributed substantial amounts of secondary production because they were very abundant. We should also note that the contributions of species that tend to be more prevalent in shallow water (19, 40) are likely underestimated in our platform estimates because these shallower depths were not well sampled on some platforms (Table S2). However, this effect will be minimized for deeper platforms because shallow depths make up a relatively small proportion of their submerged surface area.

In developing our production model, we made deliberate choices in terms of how we account for changes in the abundance, or turnover, of observed fishes over the 1-y time interval so that our production estimates would tend to be conservative. Studies of secondary fish production commonly estimate fish production as the product of average biomass and specific growth rate over a time interval, typically 1 y (2, 41; see references in Table 1). A key feature of this method is that average biomass over the interval is used. Assuming that samples are taken frequently enough to accurately quantify fish throughout the time interval, this method attempts to directly account for turnover of individuals, or changes due to predation, immigration, and emigration (2, 42). Because the data we used to estimate fish production were only from one sampling event per year, we needed to account for (*i*) losses due to mortality, (*ii*) changes due to adult immigration and emigration, and (*iii*) production from fishes that recruited (i.e., immigration of larval and pelagic juveniles) to the habitat during the time interval. To account for mortality of observed fishes we apply a length- and species-specific annual mortality function (43). This results in very low annual rates of survival for the relatively small size classes for a given species (the effect of this can be seen in Fig. S2), and thus reduces the contribution that the smaller individuals of a given species make to the Somatic Production component of the model. Another particularly conservative feature of our model is that we apply the mortality at the start of the time interval. Therefore, the production from fishes that do not survive the entire interval, but would typically be accounted for in methods where fishes can be sampled on multiple occasions during the time interval (see references in Table 1), is excluded from our estimates. Because rockfishes tend to have high site fidelity (44–46), the calculations of the Somatic Production component also assume immigration and emigration rates are equal. Furthermore, previously observed seasonal changes of the fish communities on platforms, at least for more shallow depths, consisted primarily of the presence or absence of pelagic species (40) and these types of transient, highly mobile species (e.g., jack mackerel, *Trachurus symmetricus*, Pacific sardine, *Sardinops sagax*) were excluded from the data used for our production estimates. Finally, our Recruitment Production component is also conservative in a similar manner as the mortality function, as it does not include the production of fishes that recruited to the habitat and grew for some period, but died before being observed during the annual survey (6).

Additional aspects of both the survey methodology used to collect the empirical data used in our model and previous studies of organisms on offshore platforms, would further suggest that our complete platform production estimates are likely conservative relative to estimates of fish production from other habitats. First, only fishes within 2 m of the platform exterior were counted during surveys, and fishes in the substantial water volume within the platform structure were not counted. Large numbers of rockfishes were often observed in the water column within the internal structure, particularly during years when fish densities are highest (29). Second, our model uses the same species-specific growth parameters from the literature to estimate fish growth and mortality for all habitats and therefore does not account for variability in growth or mortality across sites or habitat types. However, it has been demonstrated that rockfish and mussels (*Mytilus* spp.), one of the dominant filter-feeding invertebrates on platforms, can grow faster in these offshore artificial environments than in their corresponding natural habitats (47–49). Additionally, as we previously described, predation rates on small fishes may be lower in platform midwater habitats than at natural reefs (31). Therefore, although our model likely underestimates variability among years and sites because it does not account for these potential differences, these factors would again suggest that we are not overestimating the differences between fish production on platforms and fish production from other marine ecosystems in the literature (Table 1).

High interannual variability in rockfish recruitment is well documented (20, 50), and this was evident in the positive skew in the distributions of annual values for all metrics (see ranges in Table S1). As a result, Somatic and Recruitment Production varied highly across space (Fig. S1, see site means) and over time (Fig. S1, see site SEs, which reflect year-to-year variability). A large recruitment event will increase the Recruitment Production component that year. If the strong year class persists (e.g., 29), it will also make a substantial contribution to the Somatic Production component over the subsequent years, with the highest levels of production occurring when a given species reaches intermediate lengths (Fig. S2). Given the high temporal and spatial recruitment variability in fishes across ecosystems (51), and the prevalence of relatively few species contributing the majority of annual secondary production (this study; see references in Table 1), caution should be taken when generalizing secondary production values to an ecosystem or habitat type from a single year of data. Long-term datasets are extremely important to estimate production, an idea that has often been mentioned in the context of estimating the productive potential of artificial habitats (22, 23, 35, 38). This should be considered when designing protocols for making oil and gas platform decommission decisions and monitoring new offshore structures associated with renewable energy production.

Even though oil platforms off the coast of California were not designed to be high production artificial reefs, being among the most productive marine fish habitats that have been studied, they can provide insight into what drives high rates of fish production for both natural and artificial habitats. Management decisions will need to be made regarding (*i*) the fate of the thousands of platforms that will become economically obsolete over the coming decades (15, 16), and (*ii*) both the design and policy related to the construction and deployment of offshore renewable energy structures in the marine environment (21–23). Because human activities are threatening fish populations on natural reefs globally (52, 53), understanding the biological productivity of artificial structures is even more critical in terms of conservation of marine resources. Engineering modifications that may increase fish production could be a consideration during the design process of offshore renewable energy structures to maximize the potential conservation and fishery benefit from their deployment. These could include increasing midwater habitat surface area and complexity for recruiting fishes. If species of interest have a similar ontogenetic habitat pattern as many rockfishes, moving deeper as they grow, then local production may be further increased by providing substantial amounts of complex hard substrate habitat on the seafloor at the base of a structure (16, 19, 22, 39). Recruitment variability will also play a large role in determining the production over time at a given site. Understanding the local and regional oceanography related to larval fish delivery will be an important consideration in terms of how structure location influences fish production (37, 54). In contrast to the limited life spans of structures associated with fossil fuel extraction, estimates for decommissioning renewable energy instillations are more flexible and devices have the potential to be maintained in the marine environment for a much longer period (22). This creates the opportunity for adaptive management strategies. Combined with long-term biological monitoring, the designs of these structures can be tested in terms of fish production capabilities. Structures could then be modified as equipment has to be maintained and replaced over the longer term to increase conservation and fishery benefits.

Methods

Dataset. Data for this study were obtained from annual visual surveys conducted during daylight hours in the fall using the manned *Delta* research submersible from 1995 through 2009 and the *Dual Deepworker* in 2010–2011. A researcher aboard the submersibles identified, counted, and estimated the total lengths (to the nearest 5 cm) of all fishes along 2-m–wide belt transects. Because different subsets of sites were surveyed each fall, we used data from the 16 platforms (in bottom depths of 47–224 m) and seven natural reefs (in bottom depths of 44–311 m) (Fig. 1) that had been surveyed for at least 5 y, some of which had been surveyed up to 15 y (Table S2). At platforms, transects ran along the outside of each horizontal beam from near-surface waters to, in most instances, the bottom (Table S2). Because horizontal beam length increases with depth, survey effort is roughly proportional to the surface area of structure at each depth. Platform transects were classified into two habitat subtypes: platform midwater habitat, from water surface to 2 m above the seafloor; and platform base habitat, encompassing the bottom 2 m of the platform (Fig. 1) (19). All of the "natural reef" sites used in the analyses were primarily deep rocky outcrops and banks of high-relief bedrock and boulders of various sizes. At natural reef sites, transects typically ran parallel to rocky ridges chosen at the time of survey from previously acquired seafloor data. Further details on the survey methodology and site descriptions are available elsewhere (19, 29, 32). Annual densities (fish per square meter) at each site for each 5-cm size class in each taxon were calculated for each habitat category (i.e., natural reef, platform base, platform midwater).

Biological Metrics. In addition to calculating secondary fish production, we also calculated the total fish density and total fish biomass for each habitat type, site, and year. Observed fish lengths were converted to biomass using species-specific morphometric relationships from the literature (Table S3). To calculate the annual secondary production for a fish community, referred to here as Total Production, we developed a model based on fisheries-independent density and size structure data of fishes from visual surveys performed from a manned submersible once per year. Details of the production model are provided in *SI Methods*.

Statistical Analyses. The effect of habitat type on each metric calculated [i.e., density (fish per square meter), biomass (grams per square meter), Somatic Production (grams per square meter per year), Recruit Production (grams per square meter per year), and Total Production (grams per square meter per year)] was evaluated using linear mixed models (LMM). The first set of LMM analyses compared metrics between natural reefs and the complete platform metric. Data from platforms that never had their bases surveyed (i.e., Platform A, B, Habitat, and Hillhouse) were excluded from analyses involving complete platform scaled metrics. A second set of LMM analyses compared metrics among natural reef, platform base, and platform midwater habitat subtypes. Model formulations and the analysis procedure followed Bolker et al. (55) for an unbalanced sampling design with crossed random effects. Models were fitted with the "lmer" function in the "lme4" package (56) in R (57) using restricted maximum likelihood. In each model, habitat type was the fixed factor, combined with a random intercept term for Year and separate random intercept terms for Site within each habitat type. Considering Year as a random factor appears most appropriate due to minimal evidence of temporal autocorrelation in the autocorrelation functions for each site. Additionally, there was limited data from successive years for many sites. To meet normality assumptions, response variables were $\mathrm{Log}_{10}(x)$ transformed, or $\log_{10}(x+1)$ transformed in the case of Recruitment Production due to the presence of zeros. For each habitat type in each model, we calculated estimated marginal means and 95% confidence intervals (CIs) for the means based on 5,000 simulations using the package "arm" (58) in R. Estimated marginal means are predicted means that are calculated from the fitted model and are adjusted appropriately for any other variable in the model. In this case, those are the random factors Site and Year. These values were transformed back to their original scales for reporting. Note that these antilogs of the mean of logged data are estimates of the geometric mean, which also approximates the median on the original scale. Differences were considered significant if the 95% CIs of their marginal means did not overlap.

ACKNOWLEDGMENTS. We also thank L. Snook, M. Nishimoto, D. M. Schroeder, T. Lehmann, J. Wilson, S. Hamilton, and H. Kramp. The editor and two anonymous reviewers also provided valuable comments that led to substantial improvements in the article. Study collaboration and funding were provided by the US Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program under Agreement M12AC00003.

1. Ivlev VS (1966) The biological productivity of waters. *J Fish Res Board Can* 23(11):1727–1759.
2. Chapman DW (1968) Production. *Methods for Assessment of Fish Production in Fresh Waters*, ed Ricker WE (Blackwell Scientific Publications, Oxford), pp 182–196.
3. Waters TF (1977) Secondary production in inland waters. *Adv Ecol Res* 10:91–164.
4. Benke AC (2010) Secondary production as part of bioenergetic theory—contributions from freshwater benthic science. *River Res Appl* 26(1):36–44.
5. Randall RG, Minns CK (2000) Use of fish production per unit biomass ratios for measuring the productive capacity of fish habitats. *Can J Fish Aquat Sci* 57(8):1657–1667.
6. Kamimura Y, Kasai A, Shoji J (2011) Production and prey source of juvenile black rockfish *Sebastes cheni* in a seagrass and macroalgal bed in the Seto Inland Sea, Japan: Estimation of the economic value of a nursery. *Aquat Ecol* 45(3):367–376.
7. Powers SP, Grabowski JH, Peterson CH, Lindberg WJ (2003) Estimating enhancement of fish production by offshore artificial reefs: Uncertainty exhibited by divergent scenarios. *Mar Ecol Prog Ser* 264:265–277.
8. Johnson TD, et al. (1994) Fish production and habitat utilization on a southern California artificial reef. *Bull Mar Sci* 55(2-3):709–723.
9. Valentine-Rose L, Layman CA (2011) Response of fish assemblage structure and function following restoration of two small Bahamian tidal creeks. *Restor Ecol* 19(2):205–215.
10. Hilborn R (2011) Future directions in ecosystem based fisheries management: A personal perspective. *Fish Res* 108(2-3):235–239.
11. Levin PS, Fogarty MJ, Murawski SA, Fluharty D (2009) Integrated ecosystem assessments: Developing the scientific basis for ecosystem-based management of the ocean. *PLoS Biol* 7(1):e14.
12. Thrush SF, Dayton PK (2010) What can ecology contribute to ecosystem-based management? *Annu Rev Mar Sci* 2(1):419–441.
13. Kremen C, Ostfeld RS (2005) A call to ecologists: Measuring, analyzing, and managing ecosystem services. *Front Ecol Environ* 3(10):540–548.
14. Murawski SA (2000) Definitions of overfishing from an ecosystem perspective. *ICES J Mar Sci* 57(3):649–658.
15. Parente V, Ferreira D, Moutinho dos Santos E, Luczynski E (2006) Offshore decommissioning issues: Deductibility and transferability. *Energy Policy* 34(15):1992–2001.
16. Macreadie PI, Fowler AM, Booth DJ (2011) Rigs-to-reefs: Will the deep sea benefit from artificial habitat? *Front Ecol Environ* 9(8):455–461.
17. Bull A, Love MS, Schroeder DM (2008) Artificial reefs as fishery conservation tools: Contrasting the roles of offshore structures between the Gulf of Mexico and the Southern California Bight. *Am Fish Soc Symp* 49:899–915.
18. Holbrook SJ, et al. (2000) Ecological issues related to decommissioning of California's offshore production platforms. *Report to the University of California Marine Council by the Select Scientific Advisory Committee on Decommissioning.* Available at www.coastalresearchcenter.ucsb.edu/cmi/files/decommreport.pdf.1-41. Accessed November 1, 2013.
19. Love MS, Schroeder DM, Nishimoto MM (2003) *The Ecological Role of Oil and Gas Production Platforms and Natural Outcrops on Fishes in Southern and Central*

California: A Synthesis of Information (US Department of the Interior, US Geological Survey, Biological Resources Division, Seattle), OCS Study MMS 2003-032.

20. Love MS, Nishimoto M, Clark S, Schroeder DM (2012) Recruitment of young-of-the-year fishes to natural and artificial offshore structure within central and southern California waters, 2008–2010. *Bull Mar Sci* 88(4):863–882.
21. Nelson PA, et al. (2008) *Developing Wave Energy in Coastal California: Potential Socio-economic and Environmental Effects* (California Energy Commission, PIER Energy-Related Environmental Research Program and California Ocean Protection Council, Sacramento, CA), CEC-500-2008-083.
22. Langhamer O (2012) Artificial reef effect in relation to offshore renewable energy conversion: State of the art. *ScientificWorldJournal* 2012:386713.
23. Reubens JT, Degraer S, Vincx M (2014) The ecology of benthopelagic fishes at offshore wind farms: A synthesis of 4 years of research. *Hydrobiologia* 727(1):121–136.
24. Friedlander AM, Parrish JD (1998) Habitat characteristics affecting fish assemblages on a Hawaiian coral reef. *J Exp Mar Biol Ecol* 224:1–30.
25. García-Charton JA, Pérez-Ruzafa Á (2001) Spatial pattern and the habitat structure of a Mediterranean rocky reef fish local assemblage. *Mar Biol* 138(5):917–934.
26. Eklund AM (1997) The importance of post-settlement predation and reef resource limitation on the structure of reef fish assemblages. *Proceedings of the 8th International Coral Reef Symposium*, eds Lessios HA, Macintyre IG (Smithsonian Tropical Research Institute, Panama City, Panama), Vol 2, pp 1139–1142.
27. Page HM, et al. (2007) Trophic links and condition of a temperate reef fish: Comparisons among offshore oil platform and natural reef habitats. *Mar Ecol Prog Ser* 344:245–256.
28. Costanza R, Kemp WM, Boynton WR (1993) Predictability, scale, and biodiversity in coastal and estuarine ecosystems: Implications for management. *Ambio* 22(2-3): 88–96.
29. Love MS, et al. (2006) Potential use of offshore marine structures in rebuilding an overfished rockfish species, bocaccio (*Sebastes paucispinis*). *Fish Bull* 104(3):383–390.
30. Moser HG, Boehlert G (1991) Ecology of pelagic larvae and juveniles of the genus *Sebastes. Environ Biol Fishes* 30(1-2):203–224.
31. Schroeder DM, Love MS, Nishimoto M (2006) Comparative juvenile reef fish recruitment and mortality between offshore oil-gas platforms and natural reefs. *Bull Mar Sci* 78(1):221–226.
32. Love MS, Yoklavich M, Schroeder DM (2009) Demersal fish assemblages in the Southern California Bight based on visual surveys in deep water. *Environ Biol Fishes* 84(1):55–68.
33. Love MS, York A (2006) The relationship between fish assemblages and the amount of bottom horizontal beam exposed at California oil platforms: Fish habitat preferences at man-made platforms and (by inference) at natural reefs. *Fish Bull* 104: 542–549.
34. Bohnsack JA, Eklund AM, Szmant AM (1997) Artificial reef research: Is there more than the attraction-production issue? *Fish Aquac Isr Fig* 22(4):14–16.
35. Grossman GD, Jones GP, Seaman WJ (1997) Do artificial reefs increase regional fish production? A review of existing data. *Fisheries (Bethesda, Md)* 22(4):17–23.
36. Bernstein B, et al. (2010) *Evaluating Alternatives for Decommissioning California's Offshore Oil and Gas Platforms* (California Ocean Science Trust, Oakland, CA). Available at calost.org/pdf/science-initiatives/oil-and-gas/oil-and-gas-decommissioning.pdf. Accessed October 1, 2014.
37. Emery BM, Washburn L, Love MS, Nishimoto MM, Ohlmann JC (2006) Do oil and gas platforms off California reduce recruitment of bocaccio (*Sebastes paucispinis*) to natural habitat? An analysis based on trajectories derived from high-frequency radar. *Fish Bull* 104(3):391–400.
38. Pitcher TJ, Seaman W, Jr (2000) Petrarch's Principle: How protected human-made reefs can help the reconstruction of fisheries and marine ecosystems. *Fish Fish* 1(1): 73–81.
39. Schroeder D, Love MS (2004) Ecological and political issues surrounding decommissioning of offshore oil facilities in the Southern California Bight. *Ocean Coast Manage* 47(1-2):21–48.
40. Martin C, Lowe C (2010) Assemblage structure of fish at offshore petroleum platforms on the San Pedro Shelf of southern California. *Mar Coast Fish* 2(1):180–194.
41. Ricker WE (1975) Computation and interpretation of biological statistics of fish populations. *Bull Fish Res Board Can* 191:382.
42. Adams SM (1976) The ecology of eelgrass, *Zostera marina* (L.), fish communities. II. Functional analysis. *J Exp Mar Biol Ecol* 22(3):293–311.
43. Gislason H, Daan N, Rice JC, Pope JG (2010) Size, growth, temperature and the natural mortality of marine fish. *Fish Fish* 11(2):149–158.
44. Lowe C, Anthony K, Jarvis E, Bellquist L, Love M (2009) Site fidelity and movement patterns of groundfish associated with offshore petroleum platforms in the Santa Barbara Channel. *Mar Coast Fish* 1(1):71–89.
45. Anthony KM, Love MS, Lowe CG (2012) Translocation, homing behavior and habitat use of groundfishes associated with oil platforms in the East Santa Barbara Channel, California. *Bull South Calif Acad Sci* 111(2):101–118.
46. Matthews K (1990) An experimental study of the habitat preferences and movement patterns of copper, quillback, and brown rockfishes (*Sebastes* spp.). *Environ Biol Fishes* 29(3):161–178.
47. Blanchette CA, Helmuth B, Gaines SD (2007) Spatial patterns of growth in the mussel, *Mytilus californianus*, across a major oceanographic and biogeographic boundary at Point Conception, California, USA. *J Exp Mar Biol Ecol* 340(2):126–148.
48. Page HM, Hubbard DM (1987) Temporal and spatial patterns of growth in mussels *Mytilus edulis* on an offshore platform: Relationships to water temperature and food availability. *J Exp Mar Biol Ecol* 111(2):159–179.
49. Love MS, Brothers E, Schroeder DM, Lenarz WH (2007) Ecological performance of young-of-the-year blue rockfish (*Sebastes mystinus*) associated with oil platforms and natural reefs in California as measured by daily growth rates. *Bull Mar Sci* 80(1): 147–157.
50. Wilson JR, Broitman BR, Caselle JE, Wendt DE (2008) Recruitment of coastal fishes and oceanographic variability in central California. *Estuar Coast Shelf Sci* 79(3):483–490.
51. Caley MJ, et al. (1996) Recruitment and the local dynamics of open marine populations. *Annu Rev Ecol Syst* 27(1):477–500.
52. Mora C, et al. (2011) Global human footprint on the linkage between biodiversity and ecosystem functioning in reef fishes. *PLoS Biol* 9(4):e1000606.
53. Hoegh-Guldberg O, Bruno JF (2010) The impact of climate change on the world's marine ecosystems. *Science* 328(5985):1523–1528.
54. Watson JR, et al. (2010) Realized and potential larval connectivity in the Southern California Bight. *Mar Ecol Prog Ser* 401:31–48.
55. Bolker BM, et al. (2009) Generalized linear mixed models: A practical guide for ecology and evolution. *Trends Ecol Evol* 24(3):127–135.
56. Bates D, Maechler M, Bolker B (2013) lme4: Linear mixedeffects models using S4 classes. Available at CRAN.R-project.org/package=lme4. Accessed August 1, 2014.
57. R Core Team (2013) *R: A Language and Environment for Statistical Computing* (R Foundation for Statistical Computing, Vienna). Available at www.R-project.org. Accessed November 1, 2013.
58. Gelman A, et al. (2013) *arm: Data Analysis Using Regression and Multilevel/Hierarchical Models*. Available at CRAN.R-project.org/package=arm. Accessed August 1, 2014.
59. Galzin R (1987) Potential fisheries yield of a Moorea fringing reef (French Polynesia) by the analysis of three dominant fishes. *Atoll Res Bull* 305:1–21.
60. Day JH, Smith W, Wagner P, Stowe W (1973) *Community Structure and Carbon Budget of a Salt Marsh and Shallow Bay Estuarine System in Louisiana* (Center for Wetland Resources, Louisiana State University, Baton Rouge, LA), Publication No. LSU-56-72-04.
61. Cowley PD, Whitfield AK (2002) Biomass and production estimates of a fish community in a small South African estuary. *J Fish Biol* 61(sA):74–89.
62. Yanez-Arancibia A (1978) Taxonomy, ecology and structure of fish communities in coastal lagoons with ephemeral inlets on the Pacific Coast of Mexico. *Special Publication* (Centro Ciencias del Mar y Limnologie, Universidad Nacional Autonoma de Mexico, Mexico City), Vol 2.
63. Jones RS, Ogletree WB, Thompson JH, Flenniken W (1963) Helicopter borne purse net for population sampling of shallow marine bays. *Publications of the Institute for Marine Science* (University of Texas, Port Aransas, TX), Vol 9, pp 1–6.
64. Allen LG (1982) Seasonal abundance, composition and productivity of the littoral fish assemblage of Upper Newport Bay, California. *Fish Bull* 80(4):769–790.
65. Warburton K (1979) Growth and production of some important species of fish in a Mexican coastal lagoon system. *J Fish Biol* 14(5):449–464.
66. Teo SLH, Able KW (2003) Growth and production of the mummichog (*Fundulus heteroclitus*) in a restored salt marsh. *Estuaries* 26(1):51–63.
67. Meredith WH, Lotrich VA (1979) Production dynamics of a tidal creek population of *Fundulus heteroclitus* (Linnaeus). *Estuar Coast Mar Sci* 8(2):99–118.
68. Holcik J (1970) Standing crop, abundance, production and some ecological aspects of fish populations in some inland water of Cuba. *Věstnik Ceskoslovenské Zoologické Spolecnosti, Praha* 34:184–201.
69. Yanez-Arancibia A, Lara-Dominguez AL (1983) Environmental dynamic of Estero Pargo Inlet and structure of fish communities in daily and seasonal changes in *Rhizophora mangle/Thalassia testudinum* habitats (Terminos Lagoon, southern Gulf of Mexico). *Anales del Instituto de Ciencias del Mar y Limnologie, Universidad Nacional Autonoma de Mexico* 10:85–116.
70. DeAngelis R (1960) Brackish-water lagoons and their exploitation. *Studies and Reviews* (General Fisheries Council for the Mediterranean, Rome), Vol 12.
71. Lubbers L, Boynton WR, Kemp WM (1990) Variations in structure of estuarine fish communities in relation to abundance of submersed vascular plants. *Mar Ecol Prog Ser* 65:1–14.
72. Edgar GJ, Shaw C (1995) The production and trophic ecology of shallow-water fish assemblages in southern Australia I. Species richness, size-structure and production of fishes in Western Port, Victoria. *J Exp Mar Biol Ecol* 194(1):53–81.
73. Hellier TR, Jr (1962) Fish production and biomass studies in relation to photosynthesis in the Laguna Madre of Texas. *Publications of the Institute for Marine Science* (University of Texas, Port Aransas, TX), Vol 8, pp 1–22.
74. Faunce CH, Serafy JE (2008) Growth and secondary production of an eventual reef fish during mangrove residency. *Estuar Coast Shelf Sci* 79(1):93–100.
75. Valiela I, Wright JE, Teal JM, Volkmann SB (1977) Growth, production and energy transformations in the salt-marsh killifish *Fundulus heteroclitus*. *Mar Biol* 40(2): 135–144.
76. Elliot M, Taylor CJL (1989) The structure and functioning of an estuarine/marine fish community in the Fourth estuary, Scotland. *Proceedings of the 21st European Marine Biology Symposium, Gdansk, September 1986, 14–19* (Polish Academy of Sciences, Institute of Oceanology, Warsaw), pp 227–240.
77. Pombo L, Rebelo JE, Elliott M (2007) The structure, diversity and somatic production of the fish community in an estuarine coastal lagoon, Ria de Aveiro (Portugal). *Hydrobiologia* 587(1):253–268.
78. Allen LG, Yoklavich MM, Cailliet GM, Horn MH (2006) Bays and estuaries. *Ecology of Marine Fishes: California and Adjacent Waters*, eds Allen LG, Pondella II DJ, Horn M (Univ of California Press, Los Angeles), pp 119–148.
79. Valentine-Rose L, Rypel AL, Layman CA (2011) Community secondary production as a measure of ecosystem function: A case study with aquatic ecosystem fragmentation. *Bull Mar Sci* 87(4):913–937.

Supporting Information

Claisse et al. 10.1073/pnas.1411477111

SI Methods

Biological Metrics. All metrics were calculated annually for natural reefs and for each platform habitat subtype (midwater, base). Plus, they were also calculated for the "complete platform" scaled to per square meter of seafloor beneath the footprint of the platform. This was done by multiplying the platform midwater and platform base metrics by the submerged surface area of platform structure for each habitat type, and then dividing by the surface area of seafloor beneath the footprint of the platform (Table S2). The amount of surface area in each habitat subtype was allocated in proportion to the volume in each habitat type, calculated from platform dimensions using the formula for a truncated pyramid (1). When only one of the two platform habitat subtypes was sampled in a given year, typically due to limited visibility around the platform base (Table S2), its mean value was used for that year to calculate the annual complete platform metric.

In addition to calculating secondary fish production, we also calculated the total fish density and total fish biomass for each habitat type, site, and year. Total fish density (fish per square meter) of the observed fish assemblage is as follows:

$$D_{f,y} = \sum_{j=1}^{n} \sum_{i=1}^{m} N_{i,j,f,y}, \tag{S1}$$

where $N_{i,j,f,y}$, the density of size class i of species j at each habitat type and site f in each year y surveyed, is summed across all size classes m and species n observed. The standing stock biomass density (grams per square meter) of the assemblage is as follows:

$$B_{f,y} = \sum_{j=1}^{n} \sum_{i=1}^{m} N_{i,j,f,y} w_{i,j}, \tag{S2}$$

where $w_{i,j}$ (in grams) is the average weight at length. Average weight at length is obtained from the standard equation:

$$w_{i,j} = a_j L_{i,j}^{b_j}, \tag{S3}$$

where $L_{i,j}$ is length (in centimeters), and a and b are species-specific curve parameters (Table S3). When a length–weight equation was based on standard length (SL) or fork length (FL), the observed total length (TL) was converted using standard species-specific length–length conversion equations. In some cases fishes could only be identified to genus or species group (Table S3). For fishes or larger taxonomic groups without known conversion parameters, best professional judgment was used to assign a proxy species considering taxonomy, morphology, and relative abundance (Table S3). Transient, highly mobile species (e.g., jack mackerel, *Trachurus symmetricus*, Pacific sardine, *Sardinops sagax*) were excluded from the dataset.

Production Model. To calculate the annual secondary production for a fish community, referred to here as "Total Production," we developed a model based on fisheries-independent density and size structure data of fishes from visual surveys performed from a manned submersible once per year. Our model expands on previous versions of an approach (2), which calculated annual secondary production for all fish species in a community by subtracting current total biomass estimates from total biomass estimates predicted 1 y later using species-specific weight–length relationships and von Bertalanffy growth functions, but did not account for changes due to immigration, emigration, or mortality over the time interval. In our model, the "Somatic Production" component, which is the difference between the biomass of fishes observed during the surveys and their biomass predicted 1 y later, also accounts for losses due to mortality by including a species- and size-specific natural survivorship function (3). Because rockfishes tend to have high site fidelity (4–6), the calculations of the Somatic Production component also assume immigration and emigration of adults and postsettlement juveniles are equal. However, over the course of the 1-y time interval, additional larval and pelagic juvenile fishes will also recruit to the habitat. Therefore, we account for the production from their subsequent growth of surviving individuals in the "Recruitment Production" component of Total Production (following ref. 7).

Total Production (in grams per square meter per year),

$$P_{f,y}^{T} = P_{f,y}^{S} + P_{f,y}^{R}, \tag{S4}$$

is the sum of Somatic Production $P_{f,y}^{S}$ and Recruitment Production $P_{f,y}^{R}$. Somatic Production (in grams per square meter per year) is as follows:

$$P_{f,y}^{S} = \sum_{j=1}^{n} \sum_{i=1}^{m} N_{i,j,f,y} G_{i,j}^{W} S_{i,j}, \tag{S5}$$

where $G_{i,j}^{W}$ is the annual growth in weight and $S_{i,j}$ is the annual survivorship. Annual growth is based on the expected increase in length over the 1-y time interval $\Delta\hat{L}_{i,j}$. This is estimated according to the Fabens version of the von Bertalanffy growth function (8):

$$\Delta\hat{L}_{i,j} = \left(L_{\infty,j} - L_{i,j}\right)\left(1 - e^{-K_j}\right), \tag{S6}$$

where $L_{i,j}$ is the observed fish size class (TL; in centimeters), and $L_{\infty,j}$ and K_j are the species-specific von Bertalanffy parameters. $L_{\infty,j}$ is the mean asymptotic length and K_j is the rate at which $L_{\infty,j}$ is approached (Table S3). $G_{i,j}^{W}$ is the difference between the weight after 1 y of growth in length and its initial estimated weight at the observed length:

$$G_{i,j}^{W} = a_j \left(L_{i,j} + \Delta\hat{L}_{i,j}\right)^{b_j} - w_{i,j}. \tag{S7}$$

Annual survivorship is calculated according to ref. 8:

$$S_{i,j} = e^{-M_{i,j}}, \tag{S8}$$

where $M_{i,j}$ (1/year) is a length- and species-specific annual instantaneous natural mortality rate. To estimate $M_{i,j}$, we used the empirical formula described in ref. 3:

$$\ln\left(M_{i,j}\right) = 0.55 - 1.61\ln\left(L_{i,j}\right) + 1.44\ln\left(L_{\infty,j}\right) + \ln\left(K_j\right), \tag{S9}$$

which estimates natural mortality as a function of the observed fish size class and its von Bertalanffy parameters (Table S3). A recent review suggests this may be the best-supported estimator that is currently available (9). Mortality is applied here at the start of the production interval (i.e., fish die, then grow).

Annual Recruitment Production is defined here as the amount of new biomass produced due to the settlement, growth, and survival of larval fishes during the time interval. We estimate $P_{f,y}^{R}$ using the biomass of all fishes less than L_j^{1}, the average length at

1 y post settlement (similar to 7) as predicted by the von Bertalanffy growth function:

$$L_j^1 = L_{\infty,j}\left(1-e^{-K_j\left(t-t_{0,j}\right)}\right), \qquad \textbf{[S10]}$$

where $t_{0,j}$ is the von Bertalanffy parameter for the theoretical age when length is 0 (Table S3). This thus incorporates variability in annual recruitment patterns over the previous year, and the cumulative effect of species-specific survival and growth up to the point these fishes were observed on surveys. In most cases, we solved for $L_{i,j}^1$ by setting t to 0.5 y. However, for species where t_0 was 0.0, typically resulting from the parameter being fixed there during model fitting due to a lack of young individuals in the sample, we then set t to 1.0 y to estimate $L_{i,j}^1$. $P_{f,y}^R$ is then calculated according to Eq. **S1**, setting the density ($N_{i,j,f,y}$) to 0 for all size classes greater than size at 1 y postsettlement.

1. O'Leary M (2010) *Revolutions of Geometry* (Wiley, Hoboken, NJ).
2. Valentine-Rose L, Rypel AL, Layman CA (2011) Community secondary production as a measure of ecosystem function: A case study with aquatic ecosystem fragmentation. *Bull Mar Sci* 87(4):913–937.
3. Gislason H, Daan N, Rice JC, Pope JG (2010) Size, growth, temperature and the natural mortality of marine fish. *Fish Fish* 11(2):149–158.
4. Lowe C, Anthony K, Jarvis E, Bellquist L, Love M (2009) Site fidelity and movement patterns of groundfish associated with offshore petroleum platforms in the Santa Barbara Channel. *Mar Coast Fish* 1(1):71–89.
5. Anthony KM, Love MS, Lowe CG (2012) Translocation, homing behavior and habitat use of groundfishes associated with oil platforms in the East Santa Barbara Channel, California. *Bull South Calif Acad Sci* 111(2):101–118.
6. Matthews K (1990) An experimental study of the habitat preferences and movement patterns of copper, quillback, and brown rockfishes (*Sebastes* spp.). *Environ Biol Fishes* 29(3):161–178.
7. Kamimura Y, Kasai A, Shoji J (2011) Production and prey source of juvenile black rockfish *Sebastes cheni* in a seagrass and macroalgal bed in the Seto Inland Sea, Japan: Estimation of the economic value of a nursery. *Aquat Ecol* 45(3):367–376.
8. Haddon M (2011) *Modeling and Quantitative Methods in Fisheries* (Chapman & Hall/CRC, Boca Raton, FL), 2nd Ed.
9. Kenchington TJ (2013) Natural mortality estimators for information-limited fisheries. *Fish Fish*, 10.1111/faf.12027.

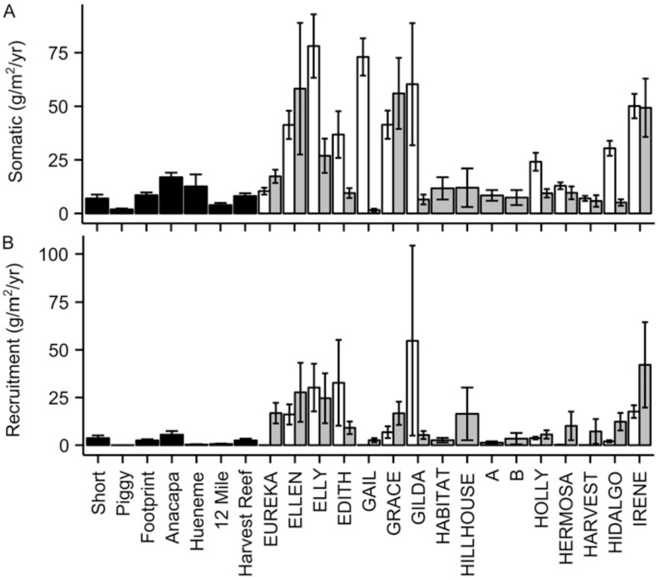

Fig. S1. Annual Production by site and habitat type. Average annual (*A*) Somatic Production and (*B*) Recruitment Production scaled to per square meter of habitat with SE error bars by habitat type (natural reefs: black bars; platform base: white bars; platform midwater: gray bars). Sites of each type (natural reefs, platforms) are ordered from south to north, and platform site names are in capital letters.

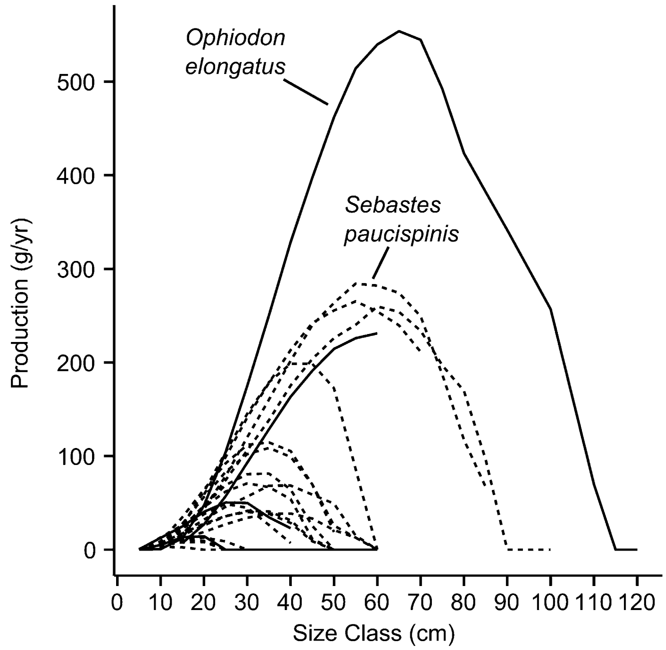

Fig. S2. Annual Somatic Production per individual observed by total length. The values are the product of $G_{i,j}^{W}$, the annual growth in weight and $S_{i,j}$, annual survivorship (Eq. **S5**, *SI Methods*) and plotted for each species that contributed at least 1% of Total Production in any habitat (Table S3). Values are plotted over the size classes that a species was observed and rockfishes, *Sebastes* spp. were plotted with dashed lines. Note that, although growth in length according to the von Bertalanffy growth equation is highest at the smallest size, production here is maximized at intermediate lengths due to the exponential increase with weight at length and low survival at small sizes. Also, production goes to 0 when fishes grow larger than the mean asymptotic length predicted by the von Bertalanffy growth function.

Table S1. Estimated marginal means and 95% confidence intervals (CIs) from linear mixed model (LMM) analyses and the range of annual values

Metric		Natural reef	Platform base	Platform midwater	Platform complete
Density, fish/m^2	Mean	0.5	1.8	0.9	15
	95% CI	(0.3–1.1)	(0.9–3.5)	(0.5–1.5)	(8.9–25.3)
	Range	(0.1, 5.3)	(0.2, 38.4)	(0.02, 29.0)	(0.6, 178.0)
Biomass, g/m^2	Mean	42.5	203.0	30.8	514.8
	95% CI	(27.4–65.8)	(131.0–312.5)	(17.5–54)	(329.9–804.1)
	Range	(4.7, 327.6)	(12.9, 1210)	(0.3, 643.5)	(48.4, 6577)
Somatic Production, g·m^{-2}·y^{-1}	Mean	5.6	28.9	7.0	110.9
	95% CI	(3.2–10.0)	(18.9–44.5)	(4.2–11.5)	(74.5–165.6)
	Range	(0.9, 31.2)	(3.0, 164.3)	(0.1, 227.6)	(11.5, 2299)
Recruit Production, g·m^{-2}·y^{-1}	Mean	1.2	2.5	4.4	55.3
	95% CI	(0.4–2.6)	(0.8–5.8)	(2.6–7.2)	(34.2–90.3)
	Range	(0.0, 17.8)	(0.0, 253.4)	(0.0, 253.9)	(0.7, 1363)
Total Production, g·m^{-2}·y^{-1}	Mean	6.9	33.3	11.9	188.9
	95% CI	(3.6–13.0)	(20.5–53.8)	(7.2–19.9)	(125.1–286.5)
	Range	(0.9, 46.1)	(4.3, 417.6)	(0.1, 379.7)	(14.8, 2608)

Mean and CI values of logged data were transformed back to their original scales for reporting. Differences were considered significant if the 95% CIs of their marginal means did not overlap.

Table S2. Survey statistics and platform structural dimensions

		Survey				Platform	
Site	Habitat	No.	Length, m	Minimum depth, m	Maximum depth, m	Surface area, m^2	Seafloor footprint area, m^2
IRENE	Base	11	207	72	72	621	2,664
	Midwater	11	193	28	50	14,243	
HIDALGO	Base	10	264	129	129	1,662	4,333
	Midwater	10	600	32	105	71,629	
HARVEST	Base	5	316	202	202	1,544	5,890
	Midwater	6	994	20	170	77,577	
HERMOSA	Base	6	262	179	179	1,319	5,203
	Midwater	6	896	41	156	83,784	
HOLLY	Base	11	186	60	60	984*	1,952*
	Midwater	13	292	7	35	20,431*	
B	Midwater	5	500	5	40	20,804	1,979
A	Midwater	7	420	5	32	20,996	1,890
HILLHOUSE	Midwater	5	375	5	35	21,206*	2,014
HABITAT	Midwater	5	527	10	65	25,766	2,242
GILDA	Base	5	195	56	62	862	2,081
	Midwater	7	247	7	41	18,626	
GRACE	Base	13	246	92	95	777	3,004
	Midwater	14	601	20	80	25,068	
GAIL	Base	14	300	220	224	1,675	5,390
	Midwater	15	1,606	10	168	104,752	
EDITH	Base	8	212	47	47	846	2,590
	Midwater	7	267	10	30	16,360	
ELLY	Base	7	220	75	75	568*	2,664*
	Midwater	7	397	12	55	13,850*	
ELLEN	Base	7	203	77	77	1,064*	2,664*
	Midwater	7	330	12	55	26,779*	
EUREKA	Base	3	281	210	215	1,809*	5,390*
	Midwater	7	1,533	15	190	107,074*	
Harvest Reef	Natural reef	11	837	98	108		
12 Mile Reef	Natural reef	5	5,938	105	130		
Hueneme Canyon	Natural reef	5	1,175	90	95		
Anacapa Passage	Natural reef	11	1,836	44	47		
Footprint	Natural reef	14	4,047	92	148		
Piggy Bank	Natural reef	5	1,501	270	311		
Short Banks	Natural reef	5	1,365	47	60		

No., number of years surveyed. Length, average total length of transects from annual surveys. Platform statistics, estimated surface area of platform structure in each habitat subtype and the surface area of seafloor beneath the "footprint" of the platform (1).

*When platform dimensions or surface area estimates were unavailable (1), the following proxies were used from platforms with similar structures from similar water depths: IRENE for ELLEN and ELLY surface and base platform dimensions, GAIL for EUREKA surface and base platform dimensions, C for HOLLY surface area and surface and base platform dimensions, and A for HILLHOUSE surface area and surface platform dimension.

1. MBC (1987) *Ecology of Oil/Gas Platforms Offshore California* (US Department of the Interior, Minerals Management Service, Pacific OCS Region, Camariilo, CA), OCS Study MMS 86-0094, pp 1–92.

Table S3. Observed taxa that contributed to production estimates and life history parameter sources

Taxon	Natural reef	Platform base	Platform midwater	Platform complete	WL	VBGF	LL
Agonidae	<0.1 (84)	<0.1 (78)		<0.1 (92)	*Xeneretmus latifrons*	*Aspidophoroides monopterygius* (1)	Ref. 1
Alloclinus holderi	<0.1 (100)				Ref. 2	*Heterostichus rostratus* (3)	
Anarrhichthys ocellatus	<0.1 (60)	<0.1 (58)	<0.1 (60)	<0.1 (69)	Ref. 4	*Cebidichthys violaceus* (5)	
Anoplopoma fimbria	<0.1 (79)				Ref. 4	Ref. 6	Ref. 7
Argentina sialis	<0.1 (52)		<0.1 (68)	<0.1 (87)	Ref. 2	Ref. 8	
Brosmophycis marginata	<0.1 (85)				Ref. 9	*Cebidichthys violaceus* (5)	
Careproctus melanurus	<0.1 (102)				Ref. 10	*Palmoliparis beckeri* Ref. 11	Ref. 7
Caulolatilus princeps	<0.1 (76)				Ref. 4	Ref. 12	
Cephaloscyllium ventriosum	0.1 (42)				Ref. 13	*Mustelus californicus*	
Chilara taylori	<0.1 (108)				Ref. 14	Ref. 8	Ref. 7
Chromis punctipinnis	2.1 (11)	<0.1 (59)	4.2 (6)	1.9 (10)	Ref. 15	*Embiotoca jacksoni*	Ref. 7
Citharichthys sordidus	<0.1 (88)	0.2 (30)	<0.1 (72)	0.1 (37)	Ref. 2	Ref. 16	
Citharichthys spp.	0.1 (49)	0.2 (29)	<0.1 (56)	0.1 (36)	*Citharichthys sordidus*	*Citharichthys sordidus*	
Cottidae	<0.1 (58)	<0.1 (62)	<0.1 (36)	<0.1 (57)	*Artedius corallinus*	*Scorpaenichthys marmoratus*	*Artedius corallinus*
Cryptotrema corallinum	0.1 (50)	<0.1 (77)		<0.1 (92)	*Alloclinus holderi*	*Heterostichus rostratus* (3)	
Cymatogaster aggregata	<0.1 (115)	<0.1 (55)		<0.1 (67)	Ref. 13	Ref. 17	Ref. 13
Embiotoca jacksoni	<0.1 (96)				Ref. 14	Ref. 18	Ref. 4
Embiotocidae	0.1 (43)	0.1 (36)	0.1 (20)	0.1 (34)	*Embiotoca jacksoni*	*Embiotoca jacksoni*	Ref. 4
Enophrys taurina		<0.1 (54)		<0.1 (64)	Ref. 19	*Scorpaenichthys marmoratus*	
Eopsetta jordani	<0.1 (109)				Ref. 4	Ref. 20	
Eptatretus spp.	<0.1 (90)				*Eptatretus stoutii*	*Heterostichus rostratus* (3)	
Eptatretus stoutii	<0.1 (89)				Ref. 21	*Heterostichus rostratus* (3)	
Girella nigricans			0.1 (23)	<0.1 (48)	Ref. 4	Ref. 22	Ref. 7
Glyptocephalus zachirus	<0.1 (98)				Ref. 23	Ref. 24	
Halichoeres semicinctus			<0.1 (66)	<0.1 (86)	Ref. 4	Ref. 25	Ref. 7
Hexagrammos decagrammus	<0.1 (62)	0.2 (31)	<0.1 (31)	0.1 (35)	Ref. 26	Ref. 27	Ref. 7
Hexanchus griseus	<0.1 (115)				Ref. 28	*Galeorhinus galeus*	
Hydrolagus colliei	1.1 (15)	<0.1 (50)		<0.1 (59)	Ref. 29	Ref. 30	Ref. 29
Hypsurus caryi	<0.1 (104)				Ref. 14	*Embiotoca jacksoni*	Ref. 7
Hypsypops rubicundus			0.1 (19)	0.1 (41)	Ref. 13	*Embiotoca jacksoni*	Ref. 7
Icelinus filamentosus	<0.1 (103)				*Clinocottus analis*	*Scorpaenichthys marmoratus*	
Icelinus spp.	<0.1 (95)		<0.1 (63)	<0.1 (83)	*Clinocottus analis*	*Scorpaenichthys marmoratus*	
Icelinus tenuis	<0.1 (115)				*Clinocottus analis*	*Clinocottus analis*	
Lepidopsetta bilineata	<0.1 (107)				Ref. 31	Ref. 32	Ref. 7
Lycodes pacificus	<0.1 (97)				Ref. 2	Ref. 33	
Lyopsetta exilis	<0.1 (91)				Ref. 2	Ref. 34	
Lythrypnus dalli			<0.1 (77)	<0.1 (93)	Ref. 19	*Heterostichus rostratus* (3)	
Medialuna californiensis			0.3 (16)	0.1 (31)	Ref. 2	Ref. 22	Ref. 7
Merluccius productus	<0.1 (70)	<0.1 (74)	<0.1 (51)	<0.1 (77)	Ref. 4	Ref. 35	Ref. 7
Microstomus pacificus	<0.1 (61)	<0.1 (67)		<0.1 (78)	Ref. 36	Ref. 36	

Table S3. Cont.

Taxon	Natural reef	Platform base	Platform midwater	Platform complete	WL	VBGF	LL
Odontopyxis trispinosa			<0.1 (76)	<0.1 (93)	Ref. 37	*Xeneretmus latifrons*	
Ophidiidae	<0.1 (86)				*Ophidion scrippsae*	*Heterostichus rostratus* (3)	Ref. 7
Ophiodon elongatus	13.9 (2)	16 (2)	0.3 (15)	9 (4)	Ref. 4	Ref. 38	Ref. 7
Oxyjulis californica	0.6 (21)		<0.1 (38)	<0.1 (62)	Ref. 4	*Halichoeres semicinctus*	Ref. 7
Oxylebius pictus	<0.1 (51)	0.2 (26)	0.3 (14)	0.3 (25)	Ref. 13	Ref. 39	Ref. 7
Paralabrax clathratus			0.1 (24)	<0.1 (49)	Ref. 13	Ref. 40	Ref. 13
Paralichthys californicus		<0.1 (65)		<0.1 (75)	Ref. 13	Ref. 41	Ref. 13)
Parophrys vetulus	<0.1 (77)				Ref. 42	Ref. 34	Ref. 7
Phanerodon atripes	0.3 (31)	0.2 (27)	0.2 (18)	0.2 (27)	Ref. 4	*Phanerodon furcatus*	*Phanerodon furcatus*
Phanerodon furcatus	0.1 (48)	<0.1 (48)	<0.1 (28)	<0.1 (50)	Ref. 14	Ref. 17	Ref. 17
Plectobranchus evides	<0.1 (72)				Ref. 19	*Cebidichthys violaceus* (5)	
Pleuronectidae	<0.1 (110)				*Parophrys vetulus*	*Hypsopsetta guttulata*	Ref. 7
Pleuronectiformes	<0.1 (56)	<0.1 (52)	<0.1 (80)	<0.1 (61)	*Citharichthys sordidus*	*Hypsopsetta guttulata*	Ref. 7
Pleuronichthys verticalis	<0.1 (112)				Ref. 2	*Hypsopsetta guttulata*	Ref. 7
Porichthys notatus	<0.1 (107)				Ref. 13	Ref. 43	Ref. 7
Pristigenys serrula			<0.1 (71)	<0.1 (90)	*Embiotoca jacksoni*	*Paralabrax clathratus*	Ref. 4
Pronotogrammus multifasciatus		<0.1 (69)		<0.1 (80)	*Paralabrax nebulifer*	*Paralabrax clathratus*	
Raja binoculata	<0.1 (75)				Ref. 4	Ref. 44	
Raja inornata	<0.1 (82)				*Raja binoculata*	*Raja binoculata*	
Raja rhina	0.1 (41)				*Raja binoculata*	Ref. 44	
Rathbunella alleni	0.1 (47)	<0.1 (42)	<0.1 (57)	<0.1 (54)	*Rathbunella hypoplecta*	*Cebidichthys violaceus* (5)	
Rathbunella hypoplecta	<0.1 (57)	<0.1 (43)	<0.1 (45)	<0.1 (52)	Ref. 9	*Cebidichthys violaceus* (5)	
Rathbunella spp.	0.2 (35)	0.2 (25)	<0.1 (53)	0.1 (30)	*Rathbunella hypoplecta*	*Cebidichthys violaceus* (5)	
Rhacochilus toxotes	<0.1 (81)	<0.1 (53)	<0.1 (59)	<0.1 (63)	Ref. 14	*Embiotoca jacksoni*	Ref. 7
Rhacochilus vacca	<0.1 (71)	0.1 (34)	<0.1 (27)	0.1 (40)	Ref. 14	*Embiotoca jacksoni*	Ref. 7
Rhinogobiops nicholsii	0.2 (33)	<0.1 (45)	<0.1 (62)	<0.1 (56)	Ref. 13	*Clinocottus analis*	Ref. 7
Scorpaena guttata	2.4 (10)	1.1 (15)		0.6 (18)	Ref. 13	Ref. 45	Ref. 13
Scorpaenichthys marmoratus		0.6 (19)	0.8 (8)	0.7 (17)	Ref. 46	Ref. 47	
Sebastes atrovirens	<0.1 (83)	0.1 (38)	0.4 (11)	0.2 (26)	Ref. 48	Ref. 49	Ref. 49
Sebastes auriculatus		1.3 (14)	0.1 (22)	0.7 (16)	Ref. 50	Ref. 50	
Sebastes babcocki	<0.1 (94)	<0.1 (68)		<0.1 (79)	Ref. 4	*Sebastes chlorostictus*	*Sebastes chlorostictus*
Sebastes carnatus	0.2 (37)	0.1 (41)	<0.1 (29)	<0.1 (46)	Ref. 13	Ref. 46	Ref. 7
Sebastes caurinus	0.5 (25)	5.8 (6)	0.6 (10)	3.5 (9)	Ref. 46	Ref. 48	Ref. 48
Sebastes chlorostictus	1.5 (14)	1.6 (10)	<0.1 (37)	0.9 (11)	Ref. 51	Ref. 52	Ref. 52
Sebastes constellatus	0.7 (20)	0.1 (35)	<0.1 (40)	0.1 (43)	Ref. 46	Ref. 51	
Sebastes crameri	<0.1 (65)	<0.1 (64)	<0.1 (47)	<0.1 (68)	Ref. 53	Ref. 54	
Sebastes dallii	<0.1 (101)	0.7 (17)	<0.1 (41)	0.4 (21)	Ref. 51	Ref. 55	Ref. 7
Sebastes diploproa	0.2 (38)				Ref. 48	Ref. 56	Ref. 57
Sebastes elongatus	0.2 (39)	0.2 (28)		0.1 (33)	Ref. 51	Ref. 58	Ref. 57
Sebastes ensifer	0.8 (18)	<0.1 (63)	<0.1 (64)	<0.1 (74)	Ref. 48	Ref. 55	Ref. 48
Sebastes entomelas	4.9 (5)	3.6 (8)	30.3 (1)	15.5 (3)	Ref. 48	Ref. 59	Ref. 57

Table S3. Cont.

Taxon	Natural reef	Platform base	Platform midwater	Platform complete	WL	VBGF	LL
Sebastes eos	<0.1 (73)	<0.1 (61)	<0.1 (75)	<0.1 (72)	Ref. 4	*Sebastes chlorostictus*	*Sebastes chlorostictus*
Sebastes flavidus	2 (12)	0.2 (24)	0.3 (13)	0.3 (23)	Ref. 51	Ref. 60	Ref. 57
Sebastes gilli	<0.1 (55)				Ref. 4	*Sebastes levis*	*Sebastes levis*
Sebastes goodei	<0.1 (53)	<0.1 (46)	<0.1 (30)	<0.1 (53)	Ref. 48	Ref. 61	Ref. 57
Sebastes helvomaculatus	<0.1 (64)	<0.1 (73)	<0.1 (67)	<0.1 (82)	Ref. 48	Ref. 62	Ref. 48
Sebastes hopkinsi	29.2 (1)	11.3 (3)	20.9 (2)	15.6 (2)	Ref. 48	Ref. 51	
Sebastes jordani	0.3 (29)	5.1 (7)	8.3 (5)	6.5 (6)	Ref. 48	Ref. 63	
Sebastes lentiginosus	<0.1 (80)	<0.1 (56)	<0.1 (58)	<0.1 (66)	*Sebastes umbrosus*	*Sebastes umbrosus*	*Sebastes umbrosus*
Sebastes levis	0.9 (17)	1.4 (11)	<0.1 (55)	0.8 (14)	Ref. 48	Ref. 48	Ref. 48
Sebastes macdonaldi	<0.1 (87)	1 (16)		0.6 (19)	Ref. 4	*Sebastes paucispinis*	*Sebastes paucispinis*
Sebastes melanops			<0.1 (39)	<0.1 (65)	Ref. 46	Ref. 64	Ref. 57
Sebastes melanosema	<0.1 (111)				Ref. 65	*Sebastes hopkinsi*	Sebastes aleutianus
Sebastes melanostomus	<0.1 (54)		<0.1 (69)	<0.1 (88)	Ref. 51	Ref. 66	
Sebastes miniatus	2.5 (9)	7 (5)	<0.1 (49)	3.9 (8)	Ref. 51	*Sebastes chlorostictus*	*Sebastes chlorostictus*
Sebastes moseri	<0.1 (78)	<0.1 (72)	<0.1 (32)	<0.1 (58)	Ref. 4	*Sebastes hopkinsi*	
Sebastes mystinus	6.5 (4)	0.4 (22)	1.4 (7)	0.8 (12)	Ref. 46	Ref. 67	Ref. 57
Sebastes nigrocinctus	<0.1 (92)				Ref. 26	*Sebastes chlorostictus*	*Sebastes chlorostictus*
Sebastes ovalis	0.3 (30)	<0.1 (71)	0.1 (21)	0.1 (42)	Ref. 51	Ref. 51	
Sebastes paucispinis	3.9 (6)	22.5 (1)	13.5 (4)	18.4 (1)	Ref. 4	Ref. 53	Ref. 57
Sebastes phillipsi	<0.1 (99)				Ref. 4	*Sebastes chlorostictus*	*Sebastes chlorostictus*
Sebastes pinniger	0.8 (19)	1.4 (13)	<0.1 (76)	0.8 (15)	Ref. 46	Ref. 68	Ref. 7
Sebastes rastrelliger			<0.1 (48)	<0.1 (73)	Ref. 69	Ref. 69	
Sebastes rosaceus	0.4 (28)	0.3 (23)	<0.1 (42)	0.2 (28)	Ref. 46	combined (55) and (46)	Ref. 57
Sebastes rosenblatti	0.5 (24)	1.4 (12)	<0.1 (34)	0.8 (13)	Ref. 51	Ref. 51	
Sebastes ruberrimus	0.1 (46)	0.1 (39)	<0.1 (50)	<0.1 (44)	Ref. 46	Ref. 70	Ref. 57
Sebastes rubrivinctus	0.1 (45)	0.6 (18)	0.1 (25)	0.4 (22)	Ref. 4	*Sebastes hopkinsi*	
Sebastes rufinanus	<0.1 (74)		<0.1 (44)	<0.1 (70)	Ref. 65	Ref. 48	*Sebastes aleutianus*
Sebastes rufus	1.7 (13)	<0.1 (60)	0.3 (17)	0.1 (32)	Ref. 51	Ref. 71	
Sebastes saxicola	<0.1 (67)	0.1 (37)	<0.1 (62)	<0.1 (45)	Ref. 51	Ref. 51	
Sebastes semicinctus	3.8 (7)	11.2 (4)	<0.1 (33)	6.2 (7)	Ref. 4	Ref. 51	
Sebastes serranoides	0.4 (27)	0.4 (21)	0.7 (9)	0.5 (20)	Ref. 46	Ref. 72	
Sebastes serriceps	0.2 (36)	0.2 (32)	<0.1 (46)	0.1 (38)	Ref. 73	Ref. 73	
Sebastes simulator	0.1 (44)	0.1 (40)	<0.1 (54)	<0.1 (51)	Ref. 2	*Sebastes ensifer*	*Sebastes ensifer*
Sebastes spp.	3.8 (8)	1.8 (9)	15.7 (3)	8 (5)	*Sebastes hopkinsi*	*Sebastes hopkinsi*	
Sebastes umbrosus	0.2 (40)	0.5 (20)	<0.1 (52)	0.3 (24)	Ref. 4	Ref. 55	Ref. 57
Sebastes wilsoni	8.1 (3)	<0.1 (44)	<0.1 (43)	<0.1 (55)	*Sebastes zacentrus*	*Sebastes hopkinsi*	*Sebastes zacentrus*
Sebastes zacentrus	<0.1 (59)	<0.1 (47)	0.1 (26)	<0.1 (47)	Ref. 65	Ref. 74	Ref. 7
Sebastolobus alascanus	<0.1 (63)	<0.1 (76)		<0.1 (85)	Ref. 75	Ref. 76	
Sebastolobus spp.	<0.1 (93)				*Sebastolobus altivelis*	*Sebastolobus altivelis*	
Sebastomus	1 (16)	0.1 (33)	<0.1 (35)	0.1 (39)	*Sebastes zacentrus*	*Sebastes ensifer*	Ref. 7
Semicossyphus pulcher	0.6 (22)	<0.1 (49)	0.4 (12)	0.2 (29)	Ref. 13	Ref. 77	Ref. 78
Stichaeidae spp.	<0.1 (69)				*Xiphister mucosus*	*Cebidichthys violaceus* (5)	

Table S3. Cont.

Taxon	Natural reef	Platform base	Platform midwater	Platform complete	WL	VBGF	LL
Synodus lucioceps	<0.1 (105)	<0.1 (70)		<0.1 (81)	Ref. 13	*Paralabrax clathratus*	Ref. 13
Torpedo californica	0.2 (32)				Ref. 14	Ref. 79	
Zalembius rosaceus	0.6 (23)	<0.1 (66)	<0.1 (78)	<0.1 (76)	Ref. 2	*Cymatogaster aggregata*	Ref. 7
Zaniolepis frenata	0.4 (26)	<0.1 (51)	<0.1 (66)	<0.1 (60)	Ref. 2	Ref. 8	
Zaniolepis latipinnis	<0.1 (68)	<0.1 (76)	<0.1 (74)	<0.1 (84)	Ref. 2	*Zaniolepis frenata*	
Zaniolepis spp.	0.2 (34)	<0.1 (57)	<0.1 (70)	<0.1 (71)	*Zaniolepis latipinnis*	*Zaniolepis frenata*	
Zoarcidae	<0.1 (66)				*Lycodes pacificus*	*Lycodes brunneofasciatus* (80)	

The percent contribution to the Total Production (and rank order in parentheses) of each taxon for each habitat type or subtype and the references for the weight–length equation (WL), Von Bertalanffy growth function (VBGF), and length–length conversion (LL) parameters used in the production model. The proxy species used is listed when the life history parameters were unavailable for the species.

1. Arbour JH, Avendaño P, Hutchings JA (2010) Aspects of the ecology and life history of alligatorfish *Aspidophoroides monopterygius*. *Environ Biol Fishes* 87(4):353–362.
2. Love MS (2011) *Certainly More Than You Want to Know About the Fishes of the Pacific Coast* (Really Big Press, Santa Barbara, CA).
3. Stepien CA (1986) Life history and larval development of the giant kelpfish, *Heterostichus rostratus* Girard, 1854. *Fish Bull* 84(4):809–826.
4. RecFIN (2009) *Pacific States Marine Recreational Fisheries Monitoring*. Available at www.recfin.org. Accessed June 21, 2012.
5. Marshall W, Echeverria TW (1992) Age, length, weight, reproductive cycle and fecundity of the monkeyface prickleback (*Cebidichthys violaceus*). *Calif Fish Game* 78(2):57–64.
6. Echave KB, Hanselman DH, Adkison MD, Sigler MF (2012) Interdecadal change in growth of sablefish (*Anoplopoma fimbria*) in the northeast Pacific Ocean. *Fish Bull* 110(3):361–374.
7. Froese R, Pauly D, eds (2012) FishBase, Version 04/2013. Available at www.fishbase.org. Accessed September 20, 2012.
8. Fitch JE, Lavenberg RJ (1968) *Deep-Water Teleostean Fishes of California* (Univ of California Press, Berkeley, CA).
9. Burge RT, Schultz SA (1973) *The Marine Environment in the Vicinity of Diablo Cove with Special Reference to Abalones and Bony Fishes* (California Department of Fish and Game, Long Beach, CA), Marine Resources Technical Report No. 19.
10. Stein DL (1980) Aspects of reproduction of liparid fishes from the continental slope and abyssal plain off Oregon, with notes on growth. *Copeia* 1980(4):687–699.
11. Tokranov AM, Orlov A (2003) Some biological characteristics of the rare, little-studied gloved snailfish *Palmoliparis beckeri* Balushkin, 1996 (Liparidae, Teleostei), in the Pacific off the northern Kuril Islands. *AQUA* 7(2):83–88.
12. Cooksey DJ (1980) Age, growth and maturity of the ocean whitefish, *Caulolatilus princeps*. MA thesis (California State University, Long Beach, CA).
13. Williams CM, et al. (2013) Morphometric relationships of marine fishes common to central California and the Southern California Bight. *Bull South Calif Acad Sci* 112(3):217–227.
14. Miller EF, Beck DS, Dossett W (2008) Length-weight relationships of select common nearshore southern California marine fishes. *Bull South Calif Acad Sci* 107(3):183–186.
15. Edwards CB, et al. (2014) Global assessment of the status of coral reef herbivorous fishes: Evidence for fishing effects. *Proc R Sci B* 281(1774):20131835.
16. Beverton RJH, Holt SJ (1959) A review of the lifespans and mortality rates of fish in nature, and their relation to growth and other physiological characteristics. *Ciba Foundation Symposium—The Lifespan of Animals.* Colloquia on Ageing (Wiley, Chichester, UK), Vol 5, pp 142–180.
17. Eckmayer W (1979) Age and growth of four surfperches (Embiotocidae) from the outer harbor of Anaheim Bay, California. *Calif Fish Game* 65:265–272.
18. Froeschke B, Allen LG, Pondella DJ (2007) Life history and courtship behavior of black perch, *Embiotoca jacksoni* (Teleostomi: Embiotocidae), from southern California. *Pac Sci* 61(4): 521–531.
19. Claisse JT, Pondella DJ, Love M, Bull AS (2014) *Biological Productivity of Fish Associated with Offshore Oil and Gas Structures on the Pacific OCS* (Vantuna Research Group, Occidental College, Los Angeles), BOEM Cooperative Agreement No. M12AC00003.
20. Lai H-L, Haltuch MA, Punt AE, Cope JM (2005) *Stock Assessment of Petrale Sole: 2004* (Northwest Fisheries Science Center, Seattle).
21. Reid R (1990) *Research on the Fishery and Biology of the Hagfish* (California Environmental Protection Agency, Carpinteria, CA).
22. Bredvik JJ, Boerger C, Allen LG (2011) Age and growth of two herbivorous, kelp forest fishes, the opaleye (*Girella nigricans*) and halfmoon (*Medialuna californiensis*). *Bull South Calif Acad Sci* 110(1):25–34.
23. Abookire AA (2006) Reproductive biology, spawning season, and growth of female rex sole (*Glyptocephalus zachirus*) in the Gulf of Alaska. *Fish Bull* 104(3):350–359.
24. Hosie MJ, Horton HF (1977) Biology of the rex sole, *Glyptocephalus zachirus*, in waters off Oregon. *Fish Bull* 75(1):51–60.
25. Adreani MS (2003) Reproductive behavior and mating system of the temperate wrasse *Halichoeres Semicinctus* (Pisces: Labridae). MA thesis (California State University, Northridge, CA).
26. Moulton LL, et al. (1977) *Puget Sound Baseline Program-Nearshore Fish Survey: Data Summary Report* (Washington State Department of Ecology, Lacey, WA), Contract No. 75-017.
27. Cope JM, MacCall AD (2005) *Status of Kelp Greenling (*Hexagrammos decagrammus*) in Oregon and California Waters as Assessed in 2005* (Pacific Fishery Management Council, Portland, OR), pp 1–158.
28. Crawford R (1993) *World Record Game Fishes 1993* (The International Game Fish Association, Pompano Beach, FL).
29. Barnett LAK, Earley RL, Ebert DA, Cailliet GM (2009) Maturity, fecundity, and reproductive cycle of the spotted ratfish, *Hydrolagus colliei*. *Mar Biol* 156(3):301–316.
30. Pauly D (1978) A preliminary compilation of fish length growth parameters. *Berichte aus dem Institut für Meereskunde an der Christian-Albrechts-Universität Kiel* (Institute of Marine Research at the Chirstian Albrechts University of Kiel, Kiel, Germany), No. 55.
31. Wildermuth D (1986) *The Recreational Fishery for Pacific Cod (Gadus macrocephalus) in Agate Pass During 1984. Progress Report* (Washington State Department of Fisheries, Seattle), Report No. 39.
32. Stark JW, Somerton DA (2002) Maturation, spawning and growth of rock soles off Kodiak Island in the Gulf of Alaska. *J Fish Biol* 61(2):417–431.
33. Erzini K (1994) An empirical study of variability in length-at-age of marine fishes. *J Appl Ichthyology* 10(1):17–41.
34. Demory R, Hosie M, Ten Eyck N, Forsberg B (1976) Marine resource surveys on the continental shelf off Oregon, 1971–74. *Oregon Department of Fish and Wildlife Completion Report* (Oregon Department of Fish and Wildlife, Salem, OR).
35. Dark T (1975) Age and growth of Pacific hake, *Merluccius productus*. *Fish Bull* 73(2):336–355.
36. Brodziak J, Mikus R (2000) Variation in life history parameters of Dover sole, *Microstomus pacificus*, off the coasts of Washington, Oregon, and northern California. *Fish Bull* 98(4): 661–673.
37. Kinnetic_Laboratories (1980) Fish and macroinvertebrate assessment program. *Final Report. Predischarge Monitoring Study, Santa Cruz Waste-Water Facility* (Kinnetic Laboratories, Santa Cruz, CA), Chap 5, KLI-80-11.
38. Jagielo T, Wallace F (2005) *Assessment of Lingcod (Ophiodon elongatus) for the Pacific Fishery Management Council* (Washington Department of Fish and Wildlife, Montesano, WA).
39. DeMartini E, Anderson ME (1980) Comparative survivorship and life history of painted greenling (*Oxylebius pictus*) in Puget Sound, Washington and Monterey Bay, California. *Environ Biol Fishes* 5(1):33–47.
40. Love MS, Brooks A, Busatto D, Stephens J, Gregory PA (1996) Aspects of the life histories of the kelp bass, *Paralabrax clathratus*, and barred sand bass, *P. nebulifer*, from the Southern California Bight. *Fish Bull* 94(3):472–481.
41. MacNair LS, Domeier ML, Chun CS (2001) Age, growth, and mortality of California halibut, *Paralichthys californicus*, along southern and central California. *Fish Bull* 99(4):588–600.
42. Holland GA (1969) Age, growth and mortality of races of English sole (*Parophrys vetulus*) in Puget Sound, Washington. *Pac Mar Fish Co Bull* 7:35–50.

43. Sak BP (1990) Age, growth and reproductive characteristics of the plainfin midshipman (*Porichthys notatus*) in Monterey Bay, with notes on seasonal movements. MA thesis (San Fransisco State University, San Francisco).
44. Gburski CM, Gaichas SK, Kimura DK (2007) Age and growth of big skate (*Raja binoculata*) and longnose skate (*R. rhina*) in the Gulf of Alaska. *Environ Biol Fishes* 80(2-3):337–349.
45. Love MS, Axell B, Morris P, Collins R, Brooks A (1987) Life history and fishery of the California scorpionfish, *Scorpaena guttata*, within the Southern California Bight. *Fish Bull* 85(1): 99–116.
46. Lea RN, McAllister RD, VenTresca DA (1999) *Biological Aspects of Nearshore Rockfishes of the Genus* Sebastes *from Central California: With Notes on Ecologically Related Sport Fishes* (California Department of Fish and Game, San Diego), Fish Bulletin No. 177.
47. Grebel JM, Cailliet GM (2010) Age, growth, and maturity of cabezon (*Scorpaenichthys marmoratus*) in California. *Calif Fish Game* 96(1):36–52.
48. Love MS, Yoklavich M, Thorsteinson LK (2002) *The Rockfishes of the Northeast Pacific* (Univ of California Press, Los Angeles).
49. Romero M (1988) Life history of the kelp rockfish *Sebastes atrovirens* (Scorpaenidae). MA thesis (San Francisco State University, San Francisco).
50. Love M, Johnson K (1998) Aspects of the life histories of grass rockfish, *Sebastes rastrelliger*, and brown rockfish, *S. auriculatus*, from southern California. *Fish Bull* 97(1):100–109.
51. Love MS, Morris P, McCrae M, Collins R (1990) *Life History Aspects of 19 Rockfish Species (Scorpaenidae:* Sebastes*) from the Southern California Bight* (National Technical Information Service, Springfield, VA), NOAA Technical Report NMFS 87.
52. Benet DL, Dick EJ, Pearson DE (2009) *Life History Aspects of Greenspotted Rockfish (*Sebastes chlorostictus*) from Central California* (National Technical Information Service, Springfield, VA), NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFSC-446.43.
53. Wilkins M (1980) Size composition, age composition, and growth of chilipepper, *Sebastes goodei*, and bocaccio, *S. paucispinis*, from the 1977 rockfish survey. *Mar Fish Rev* 42(3-4): 48–53.
54. Rogers JB, Methot RD, Builder TL, Piner K, Wilkins M (2000) Status of the darkblotched rockfish (*Sebastes crameri*) resource in 2000. *Appendix to Status of the Pacific Coast Groundfish Fishery* (National Marine Fisheries Service Newport, OR), pp 1–77.
55. Chen L-C (1971) Systematics, variation, distribution, and biology of rockfishes of the subgenus Sebastomus (Pisces, Scorpaenidae, Sebastes). *Bulletin of the Scripps Institution of Oceanography* (Scripps Institution of Oceanography, San Diego), No. 18.
56. Wilson CD, Boehlert GW (1990) The effects of different otolith ageing techniques on estimates of growth and mortality for the splitnose rockfish, *Sebastes diploproa*, and canary rockfish, *S. pinniger*. *Calif Fish Game* 76(3):146–160.
57. Echeverria T, Lenarz WH (1984) Conversions between total, fork, and standard lengths in 35 species of *Sebastes* from California. *Fish Bull* 82(1):249–251.
58. Shaw F, Gunderson D (2006) Life history traits of the greenstriped rockfish, *Sebastes elongatus*. *Calif Fish Game* 92(1):1–23.
59. Williams EH, MacCall AD, Ralston SV, Pearson DE (2000) Status of the widow rockfish resource in Y2K. *Status of the Pacific Coast Groundfish Survey Through 2000 and Recommended Acceptable Biological Catches for 2001* (Pacific Fishery Management Council, Portland, OR), pp 1–122.
60. Tagart J, Wallace F, Ianelli JN (2000) *Status of the Yellowtail Rockfish Resource in 2000* (Washington Department of Fish and Wildlife, Olympia, WA).
61. Ralston S (1998) The status of federally managed rockfish on the US West Coast. *Marine Harvest Refugia for West Coast Rockfish: A Workshop* (Pacific Fisheries Environmental Laboratory, Southwest Fisheries Science Center, Pacific Grove, CA), NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFCS-225, pp 6–16.
62. Shaw FR (1999) Life history traits of four species of rockfish (genus *Sebastes*). MA thesis (University of Washington, Seattle).
63. Pearson DE, Hightower JE, Chan JTH (1991) Age, growth, and potential yield for shortbelly rockfish *Sebastes jordani*. *Fish Bull* 89(3):403–409.
64. Bobko S, Berkeley S (2004) Maturity, ovarian cycle, fecundity, and age-specific parturition of black rockfish (*Sebastes melanops*). *Fish Bull* 102:418–429.
65. Shaw F, Wilkins M, Weinberg K, Zimmermann M, Lauth R (2000) *The 1998 Pacific West Coast Bottom Trawl Survey of Groundfish Resources: Estimates of Distribution, Abundance, and Length and Age Composition* (National Oceanic and Atmospheric Administration, Washington, DC), NOAA Technical Memorandum, NMFS-AFSC-114 (Appendices).
66. Butler JL, Jacobson LD, Barnes JT (1998) Stock assessment for blackgill rockfish. *Appendix: Status of the Pacific Groundfish Fishery Through 1998 and Recommended Acceptable Biological catches for 1999: Stock Assessment and Fishery Evaluation* (Pacific Fishery Management Council, Portland, OR).
67. Laidig TE, Pearson DE, Sinclair LL (2003) Age and growth of blue rockfish (*Sebastes mystinus*) from central and northern California. *Fish Bull* 101(4):800–808.
68. Stanley RD, Starr P, Olsen N (2009) *Stock Assessment for Canary Rockfish (Sebastes pinniger) in British Columbia Waters* (Canadian Science Advisory Secretariat, Ottawa).
69. Wilson JR, Kay MC, Colgate J, Qi R, Lenihan HS (2012) Small-scale spatial variation in population dynamics and fishermen response in a coastal marine fishery. *PLoS One* 7(12):e52837.
70. O'Connell V, Carlile D, Wakefield W (1998) *Using Line Transects and Habitat-Based Assessment Techniques to Estimate the Density of Yelloweye Rockfish (Scorpaenidae:* Sebastes*) in the Eastern Gulf of Alaska* (CM-International Council for the Exploration of the Sea, Copenhagen), 900(O: 56).
71. Watters DL, Kline DE, Coale KH, Cailliet GM (2006) Radiometric age confirmation and growth of a deep-water marine fish species: The bank rockfish, *Sebastes rufus*. *Fish Res* 81(2-3): 251–257.
72. Love MS, Westphal WV (1981) Growth, reproduction, and food habits of olive rockfish, *Sebastes serranoides*, off central California. *Fish Bull* 79(3):533–545.
73. Colton MA, Larson RJ (2007) Aspects of the life history of treefish, *Sebastes serriceps* (Sebastidae). *CCOFI Rep* 48:177–190.
74. Malecha PW, Hanselman DH, Heifetz J (2007) *Growth and Mortality of Rockfishes (Scorpaenidae) from Alaska Waters* (National Technical Information Service, Springfield, VA), NOAA Technical Memorandum NMFS-AFSC-172.
75. Ianelli JN, Lauth R, Jacobson LD (1994) Status of the thornyhead resource (*Sebastolobus* sp.) in 1994. S*tatus of the Pacific Coast Groundfish Fishery Through 1994 and Recommended Acceptable Biological Catches for 1995. Appendix 1* (Pacific Fishery Management Council, Portland, OR), pp D1–D58.
76. Rogers J, et al. (1998) Status of the shortspine thornyhead (*Sebastolobus alascanus*) resource in 1998. *Appendix: Status of the Pacific Groundfish Fishery* (Pacific Fishery Management Council, Portland, OR), pp 1–66.
77. Caselle JE, et al. (2011) Geographic variation in density, demography, and life history traits of a harvested, sex-changing, temperate reef fish. *Can J Fish Aquat Sci* 68(2):288–303.
78. Hamilton SL, Wilson JR, Ben-Horin T, Caselle JE (2011) Utilizing spatial demographic and life history variation to optimize sustainable yield of a temperate sex-changing fish. *PLoS One* 6(9):e24580.
79. Neer JA, Cailliet GM, McEachran JD (2001) Aspects of the life history of the Pacific electric ray, *Torpedo californica* (Ayres). *Copeia* 2001(3):842–847.
80. Hildebrandt N, Bergmann M, Knust R (2011) Longevity and growth efficiency of two deep-dwelling Arctic zoarcids and comparison with eight other zoarcid species from different climatic regions. *Polar Biol* 34(10):1523–1533.