MARINE RESERVES TO SUPPLEMENT MANAGEMENT OF WEST COAST GROUNDFISH RESOURCES

PHASE 2 - DRAFT CONCEPTS FOR CALIFORNIA WATERS

PREPARED BY

Richard H. Parrish
National Marine Fisheries Service
Southwest Fisheries Science Center
Pacific Fisheries Environmental Laboratory

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INTRODUCTION

Due to funding constraints the Pacific Fishery Management Council has not made progress towards the development of a network of marine protected areas (MPAs) to supplement the management of west coast groundfish resources, or any other resource managed by the Council. In contrast, the Council's actions have far outweighed its words, as huge areas have recently been closed, albeit temporarily, to fishing for groundfishes. These areas include the cowcod closures in Southern California, the California Rockfish Conservation Area between Cape Mendocino and the Mexican Border and additional area closures enacted to the north of Point Reyes and to the north of Cape Mendocino. Presently as much as 90% of the adult habitat of some groundfish species is closed to fishing. This includes both overfished and healthy species (i.e. bocaccio and chilipepper rockfish). In contrast other species have area closures in almost none of their adult habitat.

In addition the Council's actions on closed seasons, reduced daily bag limits, size limits and total prohibition on the recreational take for some species will greatly reduce the take of many nearshore groundfishes. To a large degree the Council's actions have taken the urgency out of the marine protected area issue as much of California's waters are presently closed to fishing for the groundfishes that are most in need of protection. Slope species are the principal exception and in these species the situation is geographically quite mixed. The 2003 groundfish closures provide some protection in the area north of Point Reyes (i.e. out to 250 fathoms) and in Southern California the deepwater portions of the cowcod closures provide considerable protection to the slope species. This leaves the Point Conception to Point Reyes region as the only area in California with no area closures deeper than 150 fathoms.

Eventually fishery management will progress to the point that environmental variation will be incorporated in management decisions. Eventually fishery management will progress beyond single species concepts and get to the point that ecosystem based management strategies will be enacted. Eventually fishery management will evaluate the direct effect of fishing on non-target species and the indirect effects of fishing on both economically important and non-target species. All of the above will require the use of reference/research sites that contain assemblages of fishes and invertebrates that are unfished and can therefore be used to distinguish between ecological responses caused by environmental variation versus those caused by fishing. Unfortunately, based on the life history rates and the current sizes of many groundfish stocks it will take at least a decade and possibly as much as five decades before the closed reference sites approximate the unfished state. Clearly from both research and stock status points of view we would be in a much better situation today if 30 years ago some visionary had managed to get a geographical array of closed 'research' MPAs established in the California Current System.

In addition to their importance for research MPAs can be used for two other major purposes, heritage sites (i.e., preservation of typical habitat and its associated flora and fauna for future generations) and fishery management (either as a supplemental tool or as the principal fishery management strategy). Research and heritage purposes are quite compatible and a good system or network of research MPAs will most likely also be a good network for heritage purposes; particularly if both research and heritage goals are used in the planning process. Use of MPAs for supplemental or primary fishery management may, or may not, be adequate for research and heritage purposes. For example, geographical rotation of closed areas could be a desirable fishery management technique but it clearly would not satisfy heritage purposes. It would be useful for some research roles (i.e. the determination of the recover rate of heavily exploited stocks) and not for others (i.e., those requiring unfished age structures and population densities). It is possible to design a good heritage and research MPA network that contains less than 10% of the habitat. However, due to the limited productivity of the West Coast groundfishes, a network that is intended to play a significant supplemental fishery management role will require a minimum of about 10% of the habitat and one that plays a primary role would have to be considerably larger. It is important to note that the Pacific Fishery Management Council Groundfish Fishery Strategic Plan does not include the use of MPAs as a primary fishery management tool.

Two major proposals for MPAs have recently been made for California waters and Phase 1 of the Channel Islands proposal has been enacted by the California Fish and Game Commission. It is apparent that those developing these proposals have restricted their attention to the particular piece of water for which they were given political jurisdiction and neither area will provide a good representation of the habitats or organisms in the California Current Region. A well-designed coast-wide MPA network will require careful integration of nearshore, continental shelf and slope habitats as well as a good geographical array of MPAs. In this report I have also restricted the geographical area to the area, California, in which I have political jurisdiction; and more importantly experience. A coast-wide MPA network would have to include Oregon and Washington and the optimum network for the California Current System would include Canadian and Mexican waters as well.

Given the present situation I feel that a proposal for a MPA network for Federal waters is overdue. This report examines a wide range of potential MPA networks covering the array of networks recommended in the Groundfish Strategic Plan (i.e. MPA networks occupying 5% to 20% of the area). I have developed MPA concepts that are primarily for research and heritage purposes as well as concepts that may effectively be used to supplement fishery management. To show the range of options that can be made with a constant habitat percentage three concepts are proposed with the same percentage of habitat (10%).

My hope is that these concepts will convince the Pacific Council that it should move immediately to develop a MPA network designed for research, preservation and heritage purposes. I believe that the array of concepts presented will demonstrate that a network designed to supplement the management of West Coast groundfishes cannot be determined simply by examining a range of options. Instead it is time for the Council to put some resources into a modeling effort designed to assess the supplemental role that MPAs could play in the management of the West Coast groundfish resource. Hopefully a decision will be made on the

objectives and magnitude of the MPA network before the Council launches the major effort that will be necessary to design, site and enact an MPA system that is intended to supplement the management of groundfishes.

THE CINMS AND MLPA PROPOSALS

The two principal proposals for MPAs in California are the Channel Islands National Marine Sanctuary (CINMS) proposal and the Marine Life Protection Act (MLPA) proposal. The CINMS proposal refers to a 1,133 sq. nm area within the 1,252 sq. nm Sanctuary; note that the Sanctuary extends to about 6 nm offshore of the Channel Islands. The planning for this proposal was carried out by the Marine Reserve Working Group (MRWG), which had a mixture of agency and public representatives. This process also had a separate Science Panel. The terms of reference for the Science Panel reportedly limited their considerations to 'no take' reserves that were intended to minimize the possibility of population declines under the assumption that no other fishery management regulations were in effect. The MRWG Science Panel reported that under these conditions 30-50% of the sanctuary area should be placed in 'no take' marine reserves. The Marine Reserve Working Group did not reach a consensus and the final 'preferred' reserve option was prepared by staff from the Channel Islands National Marine Sanctuary and the California Department of Fish and Game. This option consists of 25% of the area within the proposal area and it is divided into Phase 1, which is limited to State waters, and Phase 2 that includes both State and Federal waters. The preferred option includes 11 'no take' reserves, 1 conservation area (where the only allowed take is for lobster taken in the recreational fishery) and 1 conservation area (where recreational and commercial take of lobster and recreational take of pelagic finfish is allowed). Phase 1 of the CINMS proposal, was enacted by the California Fish and Game Commission and could go into effect as early as March, 2003. Phase 1 includes about 19% (114 sq. nm) of the State waters within the Sanctuary. The total area within the proposed project and subsequent federal waters phase is approximately 279 square nautical miles. Although the stated percentage is 25% actually only 22.3% of the Sanctuary would be protected as the 'project area' does not include 119 sq. nm of the Sanctuary. Further complicating the percentage issue, 4 of the marine reserves extend beyond the boundaries of the Sanctuary. The average size of the 13 MPAs is about 23 sq. nm; 4 are less than 10 sq. nm and 5 are larger than 20 sq. nm.

The California Legislature enacted the Marine Life Protection Act in 1999 and it requires the establishment of a MPA network for California State waters (3,974 sq. nm). The goals for this network are primarily based on ecosystem preservation and heritage considerations; but include commercial and recreational resource utilization and other economic, social and cultural factors. The initial draft concept was proposed in July 2001 and it describes an extremely complicated plan. The proposal has 82 MPAs with an average size of 9.1 sq. nm; 15 sites are less than 1 sq. nm and only 5 are more than 20 sq. nm. It includes 665 sq. nm, or about 16.7% of state waters. Marine reserves occupy 259 sq. nm (6.5%), marine parks 86 sq. nm (2.2%) and marine conservation areas 320 sq. nm (8.1%). There is a wide array of proposed regulations on the marine parks and conservation areas ranging from nearly 'no take' to no additional protection. Some areas (i.e. Santa Monica Bay) were considered to be conservation areas simply due to the large amount of current restrictions on fishing. I was one of the 8 Master Team members that developed the draft MLPA proposal. This proposal was 'scrapped' by the California

Department of Fish and Game and the Department is now engaged in the development of a MPA network utilizing 7 regional stakeholder committees. Each committee includes 14-17 stakeholders and the meetings are being professionally facilitated.

DIFFERENCES BETWEEN NEARSHORE AND OFFSHORE GROUNDFISH STOCKS THAT WILL INFLUENCE THE DESIGN OF CLOSED AREAS.

Many of the important exploited organisms that inhabit the nearshore area have limited mobility or are sessile (i.e. bivalves, abalone, sea urchins and marine algae) and many of the nearshore fishes are territorial and/or make very limited movements as adults (i.e. copper, quillback, gopher and brown rockfishes). Small MPAs (1 sq. nm) will therefore provide local protection for some nearshore species and moderate sized MPAs (10 sq. nm) will provide local protection for species with limited to moderate movement as adults (i.e. blue and olive rockfishes). Presently there are four California MPAs larger than 1 sq. nm that have no fishing for groundfishes; Vandenberg Marine Resources Ecological Reserve (1.8 sq. nm) being the largest. MPAs of this size may allow some species to achieve local population densities and age structures that approximate the unfished state.

In contrast, many of the important exploited offshore organisms form aggregations that are relatively mobile (i.e. Pacific Ocean perch, bocaccio, chilipepper and widow rockfishes). Some offshore species settle on the shelf as juveniles and gradually move to deeper water as they grow (Dover and English soles, sablefish, and canary rockfish) and others make seasonal inshore-offshore movements for feeding and spawning (Petrale sole and lingcod). The species with the largest groundfish stock on the west coast (Pacific hake) is highly migratory with adults moving from summer feeding grounds in the Pacific Northwest to winter spawning grounds off Southern California. Even the important exploited offshore invertebrates have considerable movement. Tagged Dungeness crab have been recovered as much as 100 miles from their release site (although most tag recoveries are made with 10 miles), Pacific Ocean shrimp make extensive but relatively short distance movements and market squid are highly mobile. Clearly small (1 sq. nm) and moderate sized (10 sq. nm) closed areas are not large enough to allow many, and probably most, of the exploited offshore species to attain age compositions and population densities within the closed areas that approach those that existed prior to fishing.

One of the major purposes of MPAs will be to provide reference sites that have populations similar to those that would occur in the absence of fishing. This type of site will be critical in future assessments of the relative effects of environmental fluctuation vs. the effects of fishing. To be effective these sites will have to be large enough to allow a broad range of species to achieve population densities and age compositions that are close to those that would occur with no fishing. MPAs intended for heritage and preservation purposes have this same requirement. Therefore, in this proposal, I have used large (100-500 sq. nm) MPAs; however, it is likely that even this size of closed area is not large enough to produce local population densities and age compositions that are close to the unfished state for some species. For example, it is obvious that these protected areas will have virtually no affect on the local age composition and densities of migratory species such as Pacific hake.

I note that that the rockfish conservation areas presently utilized by the Pacific Council for rebuilding the cowcod, bocaccio and other depressed groundfish populations in California are an order of magnitude larger than the largest closed areas utilized in this proposal. The cowcod closures (about 3,600 sq. nm) is much larger than the total area considered by the CINMS proposal (1,133 sq. nm) and about the same size as the total area of California State Waters (i.e. the 3,974 sq. nm area in the MLPA proposal). The area off California in the 2003 rockfish closures is about 8,300 sq. nm and the combined cowcod and 2003 rockfish closures are about 10,700 sq nm. Note that some of the locations in of the Cowcod Conservation Areas are also in of the California Rockfish Conservation Area.

PRACTICAL CONSIDERATIONS

In all of the MPA concepts presented here I have attempted to maintain roughly equal percentages of area in the regions north and south of Point Conception. My calculations of area are not particularly accurate because area was calculated with simple geometry and measurements taken from nautical charts using a computer program called Digital ChartKit. Final concepts should use a geographical information system (GIS) to obtain more accuracy.

There are several problems associated with the determination of the percentage of habitat included in the MPA concepts. The principal problem is that the Groundfish Strategic Plan does not define the depth range of the habitat to be included in the MPA network. Based on the cowcod closures and the 2003 groundfish closures I took the inner depth to be 20 fathoms. I somewhat arbitrarily chose 500 fathoms to be the outer depth. Without a geographical information system (GIS) and a database for depth contours I was unable to accurately determine how much area occurs between 20 and 500 fathoms off California. To estimate the area in the region north of Point Conception, I noted that the 500 fathoms line lies at an average distance from shore of about 20 nautical miles. The north-south distance between the Oregon Border and Point Conception is 453 nautical miles. I therefore used 9,060 sq. nm as the habitat area for this region (453 x 20). The Southern California region has extremely complicated topography. My calculations of habitat area for this region (12,500 sq. nm) are very rough; they included a large amount of area deeper than 500 fathoms and omitted a large amount of area shallower than 500 fathoms (Figure 1). The total area, including the area shallower than 20 fathoms, is 21,560 sq. nm.

For most MPAs I attempted to attain a continuous coverage from 20 fathoms to approximately 500 fathoms. I have exclusively used north-south and east-west boundaries for the MPAs and, for the most part, I have used round latitude and longitude numbers rather than geographical boundaries. This was primarily based on recommendations from NMFS and CDF&G enforcement personnel. I realize that boundaries based on geographical features may be superior for small, nearshore MPAs. However, the availability and low cost of GPS instruments (that give longitude and latitude) and the difficulty of identifying geographical features at night, in fog or when 10-20 miles from shore clearly indicate that simple latitude and longitude boundaries are superior for large offshore groundfish MPAs.

The use of 'square boundaries' resulted in a considerable amount of area deeper than 500 fathoms being included in the MPAs. Where submarine canyons were present I extended the MPAs into water deeper than 500 fathoms in an attempt to provide some deeper water protection and where the continental shelf was particularly wide I did not always extend the MPAs all the way to 500 fathoms. The areas deeper than 500 fathoms were included in the MPA area computations and percentages of habitat for the concepts presented, but the areas shallower than 20 fathoms were not included as I followed recent Council precedent and did not include waters shallower than 20 fathoms in the MPAs.

Application of a GIS to calculate area will provide more accurate estimates of area; however these calculations will not necessarily be more meaningful as the choice of the depth range will still be largely an arbitrary decision. Probably the best solution will be to stratify the area by meaningful depth strata and then attempt to get roughly proportional coverage by depth strata. In my opinion tailoring a MPA network to precisely fit some pre-arranged percentage of habitat will not have much biological significance, and I do not see this as an important consideration for the present draft concepts.

DESIGN ELEMENTS

DEGREE OF PROTECTION

The State of California uses three MPA classifications:

1. Marine Reserves do not allow any take of any species for commercial or recreational purposes.
2. Marine Parks do not allow any take of any species for commercial purposes; but recreational take of some species is allowed.
3. Marine Conservation Areas allow some species to be taken for commercial purposes and some species may be taken for recreational purposes.

The Pacific Council has adopted the use of the conservation area term in its recent groundfish closures; it has prohibited the take of groundfishes within the closed areas but has allowed the continued take of finfish managed under the Salmon, Coastal Pelagic Species and Highly Migratory Species Management Plans. Although the Council does not manage invertebrate fisheries it has also prohibited the use of shrimp and prawn trawls in the groundfish conservation areas because this gear takes groundfish species.

In the concepts presented here I have followed the same regulations as those in the current groundfish closures. However, it may be desirable for some or all of the MPAs to have additional species closures; for example, it may be desirable to protect coastal pelagic species in MPAs. It may be desirable to prohibit trap and pot fisheries that target invertebrates in some or all of the MPAs. The Council may also have to address the merits of establishing joint Federal/State marine reserves that extend into Federal waters.

SIZE, SHAPE AND SPACING

Determination of the optimum size and spacing of individual MPAs is dependent upon the range of larval dispersal and the amount of movement, migration or dispersal of the juveniles and adults of the affected species. Unfortunately these factors are largely unknown for most West Coast groundfish species. It is clear that the optimum MPA spacing and size for one species could provide little protection to another species. A multitude of combinations of size vs. distance between MPAs is possible and I have little insight as to what the optimum size and spacing may be. In the following draft concepts I have placed the bulk of the MPAs into three size classes, 100-130, 200-300 and 400-500 sq. nm. As I have placed the average offshore edge of the MPAs at about 500 fathoms, and this depth occurs at an average of about 20 nm offshore, this results in MPAs that are about 5-6, 10-12, and 20-25 nm on their alongshore axis. Obviously with a given percentage area the size of the MPAs determines both the number of MPAs and the average distance between them. Smaller MPAs result in more MPAs with the average distance between MPAs being smaller.

The 400+ sq. nm MPAs have roughly equal alongshore and offshore dimensions, the 200-300 sq. nm MPAs have alongshore dimensions roughly half their offshore dimensions and the 100-125 sq. nm MPAs have alongshore dimensions roughly one quarter of their offshore dimensions. Species that are relatively mobile and make alongshore movements are much more likely to move in or out of the narrow than the squarish MPAs. A permutation that I have not used, because I have attempted to achieve a full 20-500 fm depth range in each MPA, would be to make all of the MPAs squarish. However, the shape should depend upon the purpose of the individual MPA or MPA network. If the purpose is to provide a research or heritage MPA that will achieve near pristine population densities and age structures then large, squarish MPAs should be used. If the intention is to provide trophy fish for recreational anglers then smaller, elongated MPAs with a high boundary to area ratio should be used to achieve high spillover of adults. If the intention is to provide recruitment to the areas open to fishing the MPAs should be regularly spaced along the coast with relatively close spacing between MPAs.

LOCATION

The strategy I used to determine where MPAs were located relied primarily upon three factors. The dominant factor was my decision to concentrate MPAs in areas distant from fishing ports. The bulk of the MPAs to the north of Point Conception are located approximately midway between fishing ports and the majority of the MPAs south of Point Conception are located away from the mainland. The principal reason for this placement is to reduce the economic, safety and social consequences that would result from closing areas near to fishing ports. However, other things being equal, this also tends to locate MPAs in areas that currently have relatively high densities of groundfishes. This is because these areas generally have a history of lower fishing mortality than the areas closer to the ports.

The second factor was topography. I have attempted to get a representative array of habitats, depths and bottom types. Nautical charts were the major source of this information.

The third factor was the results from the CINMS and MLPA planning processes described above. Anyone familiar with the draft concepts developed during these exercises will recognize

many of the locations in the draft concepts presented here. In addition as a member of the MLPA science team I have extensively used the input gained from the 10 public hearings, 70+ small group meetings and hundreds of letters that were part of the MLPA process. I note that my exposure to the public input to the MLPA process was much greater north of Point Conception than it was south of Point Conception.

NETWORK CONSIDERATIONS

There is no single location where even a very large MPA (i.e. 1,000 sq. nm) can protect the diversity of organisms found in the California Current; therefore a system or network of MPAs will be necessary. The network would be expected to differ depending upon the purposes for which the MPA network is intended. If the major purpose of the network is to provide research and preservation sites the minimum network would be a series of MPAs that had at least one MPA in each region with a distinct faunal composition. In addition the MPA(s) for each faunal region should contain a wide range of depths, bottom types and oceanographic settings. For groundfishes a minimum California network would have an MPA near the Mexican Border for protection of sub-tropical species, an MPA in the Northern Channel Islands area where the sea surface temperature gradient is the most intense, one in Central California where historical bocaccio and chilipepper rockfish stocks were the largest and one in Northern California for the protection of the Oregonian fauna.

If the major purpose is to supplement fishery management by providing spillover of larval, juvenile and/or adult fishes from the closed areas to the areas open to fishing the network should contain a fairly large percentage of the habitat (i.e. 10-20%). Also the distance between MPAs should be small enough to insure some minimum recruitment in the areas open to fishing. If the purpose of the network is to provide the bulk of the protection in a management strategy (i.e. few traditional fishery regulations are to be utilized) a large percentage of the habitat will be required (i.e. more than 20%). Otherwise stock sizes near 40% of the virgin biomass, in accordance with the 40-10 management strategy used by the Pacific Council, are unlikely to be maintained.

HOW LARGE SHOULD THE MPA NETWORK BE?

There is little doubt that MPAs can be beneficial for protecting overexploited and poorly regulated stocks, and the Pacific Council is presently utilizing very large closed areas to rebuild depressed populations of groundfish. In addition MPAs are well suited to help manage recreational fisheries where management by limited access is undesirable. There are many situations where it may be desirable to use MPAs in a mix of management measures, for example as a trade off to closed seasons, size limits and reduced bag limits or to avoid bycatch. MPAs may also be valuable in situations where a stock has low productivity but high availability and vulnerability to fishing. However, these general observations offer little guidance for the determination of what proportion of the habitat should be protected. Clearly the principal problem associated with the development of an MPA system is the determination of how much area, or what percentage of the habitat, should be protected. There is little field evidence available to make this determination and therefore we will be forced to largely rely upon models. Proper evaluation of this question would require, at a minimum, a multi-species model and it

would preferably utilize an ecosystem model. Unfortunately it appears that at present we only have the capability to use single species models to evaluate this critical and contentious question.

The vast majority of published papers dealing with fishery management and MPAs have not addressed the role of MPAs in assisting in the management of a highly regulated fishery such as the West Coast groundfish fishery. The bulk of the published MPA models do not specify the management regime that exists outside of the MPAs. To date none of the reserve models that I have seen utilize simulations with a fishery regulated by complex rules similar to those used by the Pacific Council for groundfish. That is management by quotas that establish annual yield with a state-of-the-art control rule based on stock biomass and the 40-10 rule. In addition very few 'reserve' models have analyzed the changes in the age composition and fishing mortality exerted on the area that remains open to fishing. This is a very important consideration that should be addressed before the Council invests the resources that will be necessary to design a MPA network of the size necessary to supplement the management of West Coast groundfishes. However, it is of much lesser concern with a MPA network in the size range needed for research and heritage purposes.

To demonstrate the problems associated with the determination of the magnitude of a MPA network intended to supplement the management of groundfishes consider a stock that is at 40% of its virgin biomass and at this biomass its control rule would produce a 1,000-ton quota. The first order affect on population size is the removal of 1,000 tons of fish. This removal would be the same if the percentage of habitat in MPAs were 0%, 10% or 30%. However, after a decade the biomass and age composition in the area open to exploitation and the fishing effort required to take a 1,000-ton quota would be quite different under each of the above scenarios. Models based on information from data rich West Coast groundfishes should be developed to assess the differences between the yields, costs of fishing and stock sizes under various percentages of closed area. These models should use harvest rates based on the current control rules for the species modeled.

Even without models it is obvious that the first order population effect will be determined by the control rule. The differences in productivity due to the sizes, shapes and locations of individual MPA networks will be secondary. These secondary differences will primarily be dependent upon two factors, geographical variations in life history rates and density-dependence in life history rates. If there are significant geographical variations in life history rates there are likely to be areas that are population sources and others that are sinks. If a large proportion of the sources of recruitment are inside of MPAs and if most of the sinks are outside the MPA network there will be a positive effect both inside and outside of the MPAs. The reverse is also true. Unfortunately we have virtually no information on the geographical variation in recruitment or most other life history rates. This implies that modeling will necessarily focus on density-dependent variations in life history rates; primarily egg production, recruitment, juvenile survival and growth. If the density-dependence of some these rates are large, MPAs could produce significant changes in the productivity of the stock. However, in spite of extensive information on the population dynamics of West Coast groundfishes no one has noticed significant density-dependence in egg production, or in the survival rates or growth rates of juveniles or adults. In addition for most West Coast groundfishes both recruitment and surplus production have proven to have little density-dependence. In fact this is the primary reason for our present dilemma.

DRAFT CONCEPTS

Eight draft concepts with a range of area percentages (4.5-20%), number of MPAs (4-20) and MPA sizes (75-504 sq. nm.) are included in this analysis (Figures 2-9, Tables 1-2). I have included some concepts designed for research and heritage purposes and others primarily intended to supplement traditional fishery management strategies. The intention is not to suggest that any of these concepts is preferable to another; rather the purpose is to show what a range of options looks like with different sized MPAs and different percentage protection. In addition, I have used the concepts to discuss the strengths and weakness of different MPA configurations with respect to their use for research and heritage networks or for supplemental fishery management networks. The chart for each concept includes the current Cowcod, and California Rockfish Conservation Areas and the other 2003 groundfish closures. This will allow the present situation to be directly compared with each draft concept. The MPAs boundary lines, as drawn, extend to the shore; however, the areas inside of the 20-fathom line are not included in the MPAs.

RESEARCH AND HERITAGE MPA NETWORKS

Three research concepts with 4.5%, 6% and 7.5% of the total habitat area in MPAs are presented. The principal purpose of MPA networks of this general size is to provide areas where many species should be able to attain near pristine population densities and natural age structures. Reference sites of this type will be necessary in the determination of the relative effects of fishing vs. environmental change (i.e. global climate change, climatic regime effects and pollution) and for assessment of the effects of fishing on no-target organisms.

An increasing proportion of the public is becoming aware of the advantages of MPAs in resource protection for heritage and preservation purposes and this size of MPA network should also be effective for these purposes. MPA networks that occupy this percentage of the total habitat are being developed in a number of other countries primarily because it is thought that this size of MPA networks are large enough to preserve heritage and research sites with near-pristine conditions for future generations. However, the relatively remote locations and the fact that the proposed MPAs do not include depths less than 20 fathoms makes them poor candidates for use as wild parks where the public will be have access to view or use the resources protected by the networks. MPAs that the public can actually use will primarily be in water that is shallow enough for the use of scuba gear and they will receive more use if they are near ports or other sites with public access to the ocean.

The size of these research and heritage concepts are too small to provide much assistance in maintaining stock size or recruitment to sustain fisheries and they should therefore not be relied upon to provide much assistance in maintaining viable fisheries. Their role in supplementing traditional fishery management will primarily be to guard against management errors or adverse climatic events. However, MPA networks of this size will provide insurance, as they are large enough to prevent the populations of many species from declining to the level where they would become candidates for the Endangered Species Act.

The 4.5% Concept

The 4.5% concept has 9 MPAs with 4 north of Point Conception (Figure 2). The size of MPAs averages 108 sq. nm and the MPAs average about 6 nm in the along shore dimension and 18 nm in the offshore dimension. This configuration is good at providing spillover of large fishes that can be taken in the adjacent fished areas and it could be used to evaluate the potential of MPAs for assisting in fishery management. Due to the larger number of MPAs this network has a wide range of habitat types and the spacing between MPAs is 40-70 nm in Southern California and 85-150 nm North of Point Conception. This should allow relatively wide dispersal of pelagic larvae to the entire region; however, the larval production from this size of a network will be only a small percentage (i.e. 4.5 to 7.5%) of that that occurred prior to fishing and it certainly is not large enough to maintain healthy populations outside of the MPAs

MPAs of the size and shape used in this concept are likely to be on the small size for achieving near-pristine densities and age structures of relatively mobile fishes and invertebrates. Specifically the MPAs in this concept have quite narrow alongshore dimensions and it is likely that species with even minor alongshore movements will have significant numbers leaving and the entering the closed areas. This implies that this concept will have some drawbacks if its principal purpose is to provide preservation areas and sites for ecological research. Enforcement costs would be relatively high for a research and heritage network with this configuration due to the relatively large number of MPAs and the increased distance in boundaries caused by the elongated shapes of the MPAs.

The 6% Concept

The 6% concept (Figure 3) has fewer (4) and larger (average 320 sq. nm) MPAs than the 4.5% concept. This concept was an attempt to achieve a network with larger MPAs that should have a better chance to attain near pristine conditions. The trade off for increased size of individual MPAs is achieved by a substantial increase in the spacing between MPAs; the distance between MPAs in this concept varies between 100 and 250 nm. This concept has the minimum number of sites that could be considered to provide a research network as sites are so widely spaced that each site contains a different assemblage of organisms. Each of the sites is located in areas that have high wind and current speeds; dispersal of pelagic early life history stages will be near the maximum possible with a small number of sites. However, the Punta Gorda, Point Sur and Richardson Rock MPAs also contain areas with considerable protection from wind and offshore currents where larval retention would be expected to be high. When this factor is combined with the large size of the MPAs it is likely that local recruitment may allow these MPAs to maintain relatively high recruitment rates even if the stock sizes outside of the MPAs is quite low.

An MPA network with this configuration would be intended primarily for preservation and heritage purposes. It also has high potential for ecological research and evaluation of the relative effects of fishing and environmental conditions. However the remote locations and high energy oceanographic conditions of the MPA sites will make the costs and difficulty of carrying out research relatively high.

The 7.5% Concept

The 7.5% concept (Figure 4) has 6 MPAs with an average size of 270 sq. nm. This network is an attempt to attain a research and heritage network that has relatively large MPAs, moderate spacing between MPAs (between 70 and 150 nm) and a broad range of habitat types and oceanographic settings. Thus it becomes the largest of the research MPA networks. The three sites not present in the 6% concept are less remote and more easily studied than those in the 7.5% concept and a MPA network with this configuration should be very good for research and heritage purposes and it is approaching the size where it may provide some assistance in maintaining populations outside of the network. With the configuration in this concept the assistance would be expected to be based on larval production and recruitment rather than spillover of adult animals

MPA NETWORKS TO SUPPLEMENT MANAGEMENT

Before designing a MPA network to supplement fishery management specific objectives of the network should be established. One way to proceed with this determination is to establish a network core that achieves research and heritage goals and then add to this core to achieve the specific supplemental protection intended to assist with the management of the fishery. For example, the core could look like one of the three previously described research and heritage networks. The core MPAs would be intended to be permanent whereas MPAs intended to supplement fishery management may, or may not, be permanent and they may, or may not, be established at the same time as the network core. Also MPAs intended to supplement fishery management should be designed to be part of a total management strategy, not simply an additional layer of management. For example, a management strategy based on individual transferable quotas and MPAs could produce an efficient management regime that would completely do away with trip limits and other temporal catch limits.

The research and heritage core should have a representative array of habitats providing a good mix of the depth, geographical and oceanographic settings. The fishery management part of the network could have this same mix of habitats; however, it may be preferable to design this part to protect the specific habitats of individual species. It is possible that the fishery management part of the network could be based on system of rotating, rather than permanent, area closures. It is clear that the use of MPAs to supplement the management of groundfishes will be an exercise in adaptive management. This is why it will be important to identify the individual MPAs that are intended for research and heritage goals and those that are intended for supplementing fishery management. The research and heritage MPAs should be considered to be quasi-permanent whereas the fishery management MPAs will be expected to evolve if they prove to be successful or disappear if they prove to be an ineffective management tool.

Concepts with permanent and temporary MPAs

Although not designed as a formal MPA network, in fact California presently has an extremely large network of groundfish conservation areas (i.e. about 10,700 sq. nm, or 49.6% of the total 21,650 sq. nm area considered in this report). The major objective of this MPA network is to

insure that seriously overfished species will be allowed to recover to healthy biomass levels. Of course, the amount of area in the temporary MPAs would be expected to vary over time as the depressed stocks recover and the value of closed areas for fishery management becomes better understood.

Establishment of a research and heritage core similar the three previously described concepts (Figures 2, 3, and 4) would produce a MPA network with about 1,000 to 1,600 sq nm in permanent research and heritage MPAs; note that more than half of the area of the three research MPA networks is already in existing conservation areas. The combination of these permanent MPAs with the existing rockfish conservation areas would result in a MPA network with 4.5-7.5% of the area in permanent conservation areas and about 46-48% of the area in temporary conservation areas. The permanent MPAs would include a wide range of species and a diverse range of habitats; whereas the temporary conservation areas are focused on the habitats of individual depressed species.

The 10% Concepts

Three concepts with 10% of the habitat in MPAs were developed. This was done to show the large amount of variation that can be achieved by manipulating the size and number of MPAs without changing the percentage of habitat in the network. The concepts have 20 MPAs with an average size of 108 sq. nm, 10 MPAs with an average size of 217 sq. nm and 5 MPAs with an average size of 435 sq. nm. Note that I have attempted to maintain roughly equal size and shapes of MPAs within each of the 10% concepts; obviously it may be desirable to have a 10% concept that includes several sizes of MPAs.

The 10% concept with 20 MPAs (Figure 5) has the maximum number of MPAs of all 8 concepts and the average size and shape of MPAs is similar to that in the 4.5% concept (108 sq. nm). This 10% concept has the smallest distances between MPAs of any of the networks presented and it has the maximum distance in boundaries. This suggests that this network would have the maximum exchange or spillover of organisms between protected and unprotected areas. Due to the large number of sites this concept has the maximum range of habitat and oceanographic conditions and this configuration also allows the maximum dispersal of pelagic larvae produced within the protected area. There is also considerable scope for replicate sites for research purposes. In addition many sites are closer to ports, which allows the benefits of protected areas to be available to the maximum number of people and it also would allow the network to be more easily studied. This combination implies that it would also be the most expensive to enforce. The principal weakness of the configuration is that the relatively small size and elongate shapes of most of the MPAs reduce their value for heritage and preservation purposes.

The 10% network with 10 MPAs (Figure 6) is based on MPAs that vary is size from 205-254 sq. nm with the exceptions of the Santa Cruz Island MPA (130 sq. nm) and Encinitas MPA (150 sq. nm). Offshore MPAs have squarish shapes and MPAs adjacent to the mainland have an alongshore axis with about half the length of the offshore axis. This network could be considered to be the moderate or mid-point of the 8 concepts presented; because, it is has mid-sized MPAs and also is in the middle of the range of percentages and spacing for the concepts.

The 10% network with 5 MPAs (Figure 7) has two large (477 and 441 sq. nm) MPAs to the north of Point Conception and one 254 sq. nm and two near 500 sq. nm MPAs in Southern California. Due to the large size of individual MPAs this network should be one of the best at attaining near pristine densities and age structures of organisms. It therefore is a good configuration for heritage and preservation purposes and for ecological research. However, like the 7.5% concept it has quite wide spacing between MPAs and it may therefore be among the worst at assuring a wide and even distribution of larvae. Networks of this type would appear to be best suited to a management regime that does not allow the spawning biomass of individual species to fall to low levels in the areas open to fishing. Also due primarily to the small number of MPAs and its high area to boundary ratio it would be among the easiest to enforce.

The 15% Concept

The 15% Concept has 10 MPAs with 5 north and 5 south of Point Conception and it includes both 200+ and 400+ sq. nm MPAs (Figure 8). The average size of MPAs is somewhat smaller north of Conception to reduce the distance between MPAs in this region. This type of network is approaching the size that may offer considerable assistance in maintaining population size and recruitment in heavily exploited species as well as providing large replicate MPAs for research purposes. This concept has a representative array of habitat types and theoretically, once a system of this type has been in place for a decade or more, it should prevent stock sizes of a wide range of species from reaching the level (10% of virgin stock size) that requires rebuilding under the 40-10 management provision.

The 20% Concept

The 20% concept has 9 MPAs and it is primarily composed of 400+ sq. nm MPAs (Figure 9). MPA networks of this magnitude would be large enough to be used to assist in the recovery of depleted stocks and, after they had been in place for a decade or so, would probably provide considerable insurance against stock declines associated with overexploitation and/or unfavorable regime scale environmental changes. MPA networks of this size may be approaching the size where increases in size would come at the expense of decreased long-term economic yield. The principal reasons for this is that it has yet to be demonstrated that 100% of MSY can be obtained from fishing only 80% of the habitat. Also fishing effort (costs) will have to increase to catch a given quota due to decreased fish density in the area open to fishing. Of course if a large proportion of recruitment comes from the spawners in a relatively small proportion of a given species habitat it is possible that proper placement of MPAs could result in increased yield from that species. However, the geographical reproductive sources would have to be common to a wide variety of species before it would be likely that the total yield of groundfish could be increased.

DISCUSSION

In effect the Pacific Council has already established extremely large, temporary MPAs and these MPAs are the most significant management measure currently being used to rebuild several depleted rockfish stocks. As the depleted stocks begin to rebuild it is likely that it will be desirable to phase out the closed areas rather than reopen the entire area all at once. This is

definitely not the situation that was expected when the Groundfish Strategic Plan was developed. In fact most people would have thought that the Council would be in the position where it was phasing in a MPA network; not waiting for favorable environmental conditions that will allow the depleted stocks to rebuild to the state where the Council can start phasing out area closures.

It is possible that problems with other species (i.e. deep slope species) will result in area closures with different geographical and depth boundaries designed to assist in their recovery. It is possible that that the Council will be phasing in area closures for some species at the same time that it is phasing out area closures for others. Area closures are definitely a tool that will be used for West Coast groundfish management for the foreseeable future.

To date the Council has put very limited resources into assessment of temporary area closures or permanent MPAs. It is clear that both temporary and permanent MPAs need to be assessed as management tools and the Council needs to broaden its analytical research capabilities to include simulation models with geographical resolution. In particular analyses need to be carried out to assess the response of stocks to different sized MPA percentages when these stocks are managed with state of the art control rules.

Marine protected areas are presently very popular with the public; undoubtedly this is partially due to the perception that fish stocks are in decline worldwide. An increasing number of people believe that the only way we will be able to preserve natural marine populations is to remove substantial areas from exploitation. Given the present situation with West Coast groundfishes there appears to be little downside that would be realized if the Council was to immediately establish an MPA network similar to the research and heritage networks described here; as little additional area would have to be closed to fishing. However, MPA networks of the size necessary to supplement fishery management (i.e. 10-25% of the habitat) need to be assessed with models based on data rich West Coast groundfishes before this type of permanent MPA network should be developed.

RECOMMENDATIONS

1. The Pacific Council should quickly proceed with the development of a reference, or research, MPA network for groundfishes. This network should be based on, or at least include portions of, the present groundfish closures and it should be designed to provide significant areas for heritage and preservation purposes. Action on a Federal MPA network at this time would foster the coordinated development of an integrated network for both State and Federal waters.

2. The first order of business, in developing a marine protected area network to supplement the management of west coast groundfishes, should be to carry out model simulations designed to provide the information necessary to determine the approximate percentage of the habitat that should be included in this type of MPA network.

3. The modeling effort should focus on the age composition and population densities inside and outside of MPAs as well as the yield and fishing effort that will result from different sized

MPA networks. This modeling should be carried out for several important data rich species and the models should be run with the existing control rules applicable to the individual species. Models should include scenarios with healthy stock size as well as stocks that are in a rebuilding status. This type of analysis should result in information that will assist the Council in making the critical decision regarding the percentage of area that should be included in an MPA network designed to supplement the management of West Coast groundfishes.

4. In addition to permanent MPAs the Council should put a priority on analyses designed to evaluate the use of temporary MPAs to assist in rebuilding depleted stocks. Specifically it should examine how and when to scale back the present very large area closures as the overfished bocaccio, cow cod, canary, yelloweye and dark-blotched rockfishes begin to recover.

Table 1. Information on MPA concepts.

Concept	4.5%	6%	7.5%	10%	10%	10%	15%	20%
Text Figure	2	3	4	5	6	7	8	9
No. of MPAs	9	4	6	20	10	5	10	9
Area (sq. nm)	973	1282	1618	2158	2173	2176	3226	4278
Average MPA size	108	320	270	108	217	435	323	475
% Total area	4.5	5.9	7.5	10.0	10.1	10.1	15.0	19.8
% North of P. Conception	4.5	5.8	7.6	9.9	9.9	10.1	15.3	19.9
% South of P. Conception	4.5	6.1	7.4	10.1	10.2	10.1	14.7	19.8

Area north of Point Conception - 9060 sq. nm
Area south of Point Conception – 12500 sq. nm

Table 2. Boundaries and sizes (sq. nm) of conservation areas in MPA concepts.

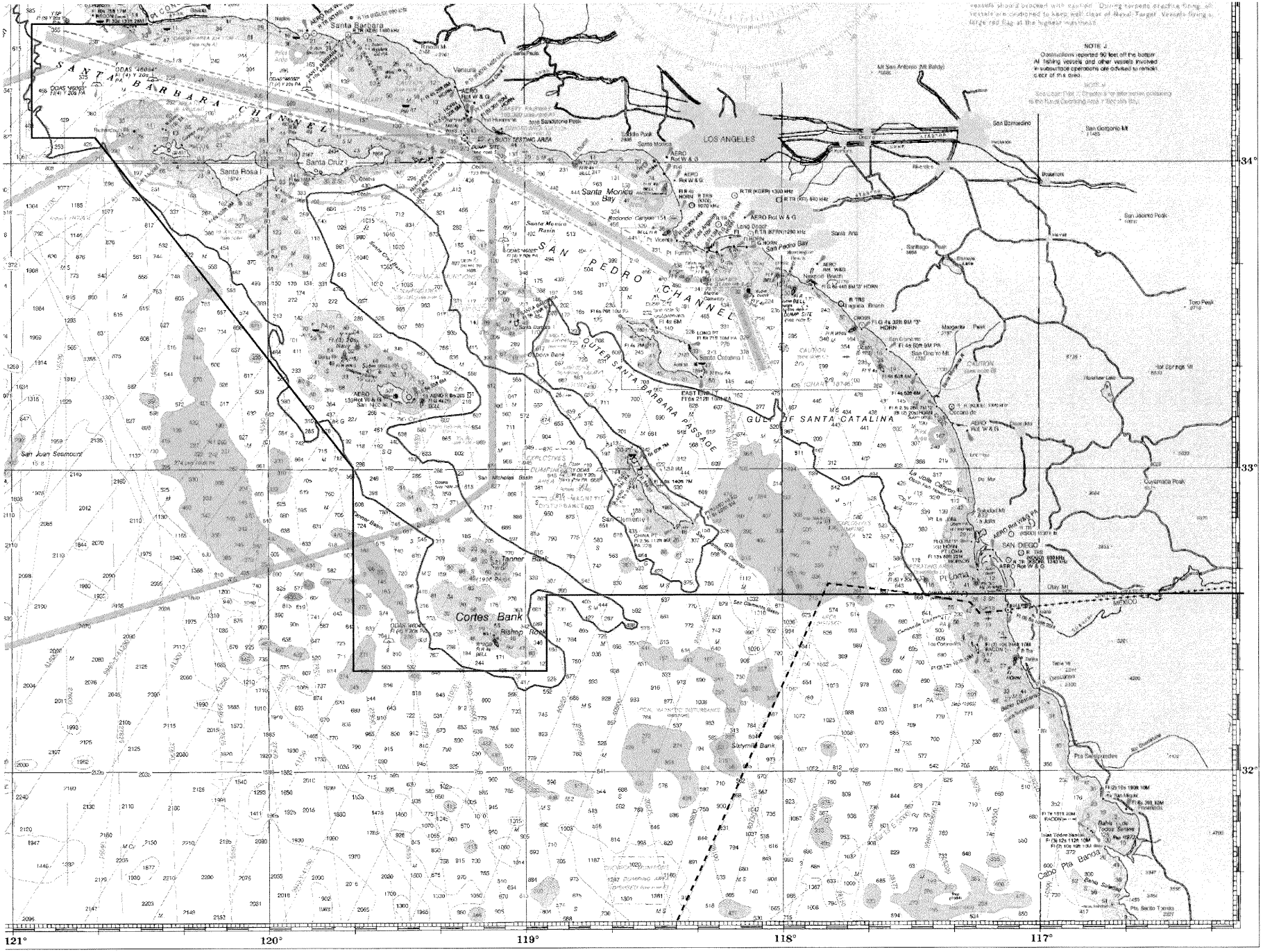
MPAs	Boundaries North n lat.	South n lat.	West w long.	East w long.	Figure Area	2 4.5%	3 6%	4 7.5%	5 10%	6 10%	7 10%	8 15%	9 20%
Pelican Point	42 0	41 53	124 40		120				120				
Klamath	41 37	41 31	124 35		109	109							
Klamath	41 37	41 25	124 35		226			226		226		226	
Reading Rock	41 37	41 15	124 35		424								424
False Cape	40 34	40 27	124 50		127				127				
Punta Gorda	40 25	40 0	124 42	124 13	477						477	477	
Punta Gorda	40 20	40 0	124 35	124 13	276		276						
Elk	39 9	39 4	124 10		95	95			95				
Black Point	38 50	38 30	123 55		443								443
Black Point	38 46	38 34	123 50		220			220		220			
Farallones	37 45	37 35	122 55	123 25	233							233	
Farallones	37 44	37 38	122 58	123 20	100				100				
Ano Nuevo	37 9	37 4	122 48		115	115			115				
Big Sur	36 17	36 12	122 15		100				100				
Big Sur	36 15	36 4	122 10		245		245	245		245		245	
Big Creek	36 15	35 55	122 5		441						441		441
Cambria	35 35	35 30	121 30		93	93			93				
Point Sal	34 54	34 45	121 10		205					205		205	
Point Arguello	34 54	34 34.7	121 10		494								494
Point Arguello	34 42	34 34.7	121 5		147				147				

Table 2. Continued

MPAs	Boundaries North n lat.	South n lat.	West w long.	East w long.	Figure Area	2 4.5%	3 6%	4 7.5%	5 10%	6 10%	7 10%	8 15%	9 20%
Richardson Rock	34 15	34 0	120 50	120 30	247					247			
Richardson Rock	34 14	34 2	120 50	120 18.4	294			294				294	
Richardson Rock	34 14	34 58	120 50	120 18.4	393		393						
Richardson Rock	34 13	34 6	120 40	120 18.4	124	124			124				
San Miguel	34 10	33 43	120 45	120 17	502						502		502
Santa Cruz	34 10	34 2	119 40	119 20	130				130	130			
Big Sycamore		33 48	119 3	118 55	110	110			110				
Gull Island	33 55.2	33 45	119 55	119 45	85				85				
Cow Cod North	33 50	33 30	119 30	119 0	498							498	498
Santa Barbara Is	33 28.5	33 13	119 10	118 50	254					254	254		
Santa Barbara Is	33 27.5	33 15	119 5	118 55	105				105				
Catalina Is	33 20	33 14	118 22	118 0	104				104				
San Nicolas Is	33 15	33 2	119 40	119 30	104	104			104				
San Nicolas Is	33 15	33 0	119 50	119 30	246					246		246	
Cow Cod Central	33 15	33 0	119 50	119 10	486								486
Encinitas	33 8	32 58	117 55		296			296				296	
Encinitas	33 8	32 52	117 50		488								488
Encinitas	33 5	33 0	117 42		108	108			108				
Encinitas	33 5	32 58	117 45		150					150			
San Clemente Is W	32 58	32 53	118 57		100				100				
San Clemente Is E	32 58	32 53		118 5	100				100				
Cortez Bank	32 40	32 20	119 30	119 10	337			337					
Cow Cod South	32 40	32 20	119 30	119 8	368		368						

Cow Cod South	32 40	32 20	119 30	119 0	504						504	504	504
43 Fathom Spot	32 40	32 30	118 0	117 50	75			75					
Cortez Bank	32 35	32 20	119 10	118 50	251				251				
Cortez Bank	32 30	32 20	119 14	119 0	117	117		117					

Figure 1. Area used to calculate area in Southern California (i.e. the area inshore of the black line). Green contour lines show basins deeper t , 500 fathoms and solid green areas show banks shallower than 500 fathoms.



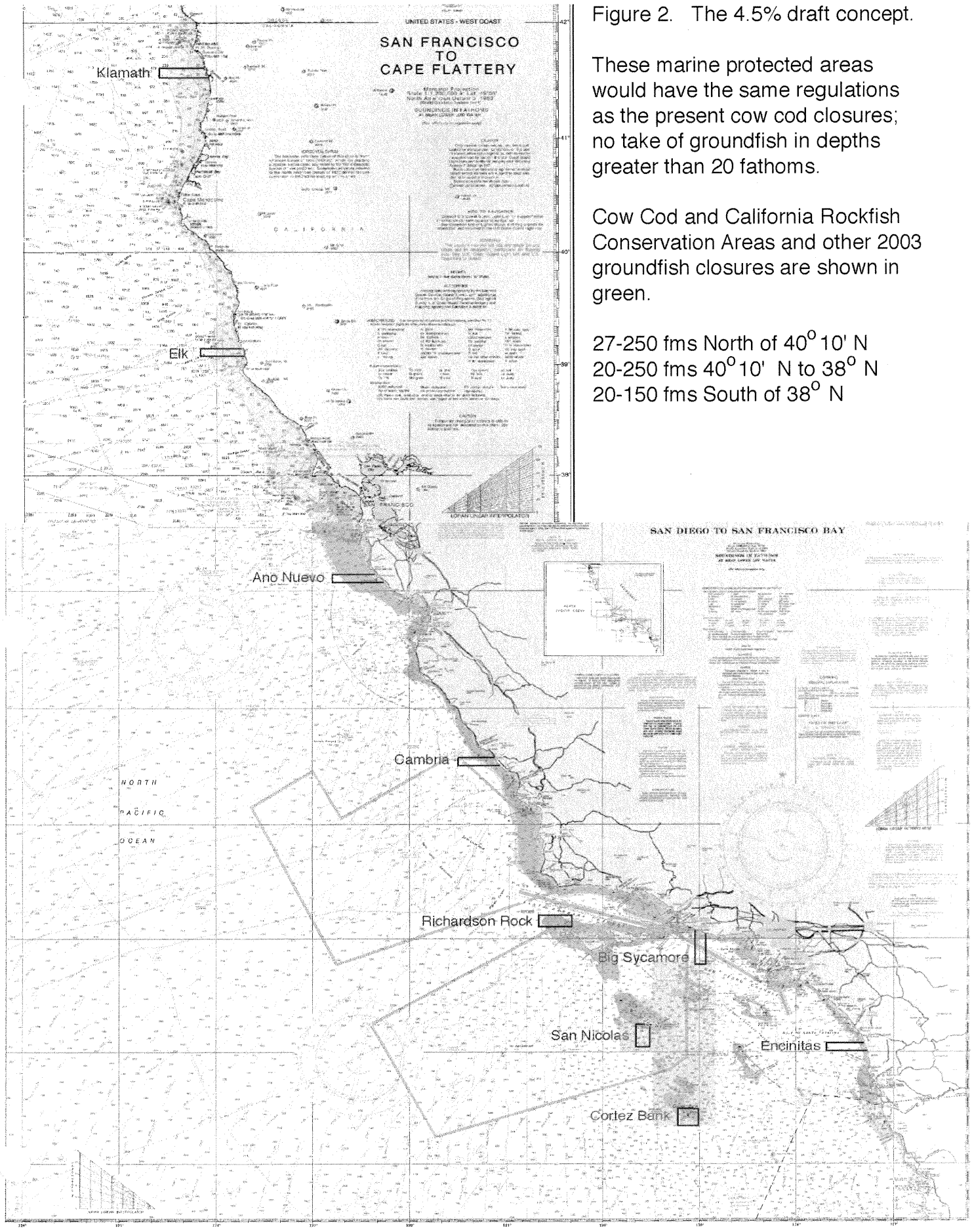


Figure 2. The 4.5% draft concept.

These marine protected areas would have the same regulations as the present cow cod closures; no take of groundfish in depths greater than 20 fathoms.

Cow Cod and California Rockfish Conservation Areas and other 2003 groundfish closures are shown in green.

27-250 fms North of 40° 10' N
20-250 fms 40° 10' N to 38° N
20-150 fms South of 38° N

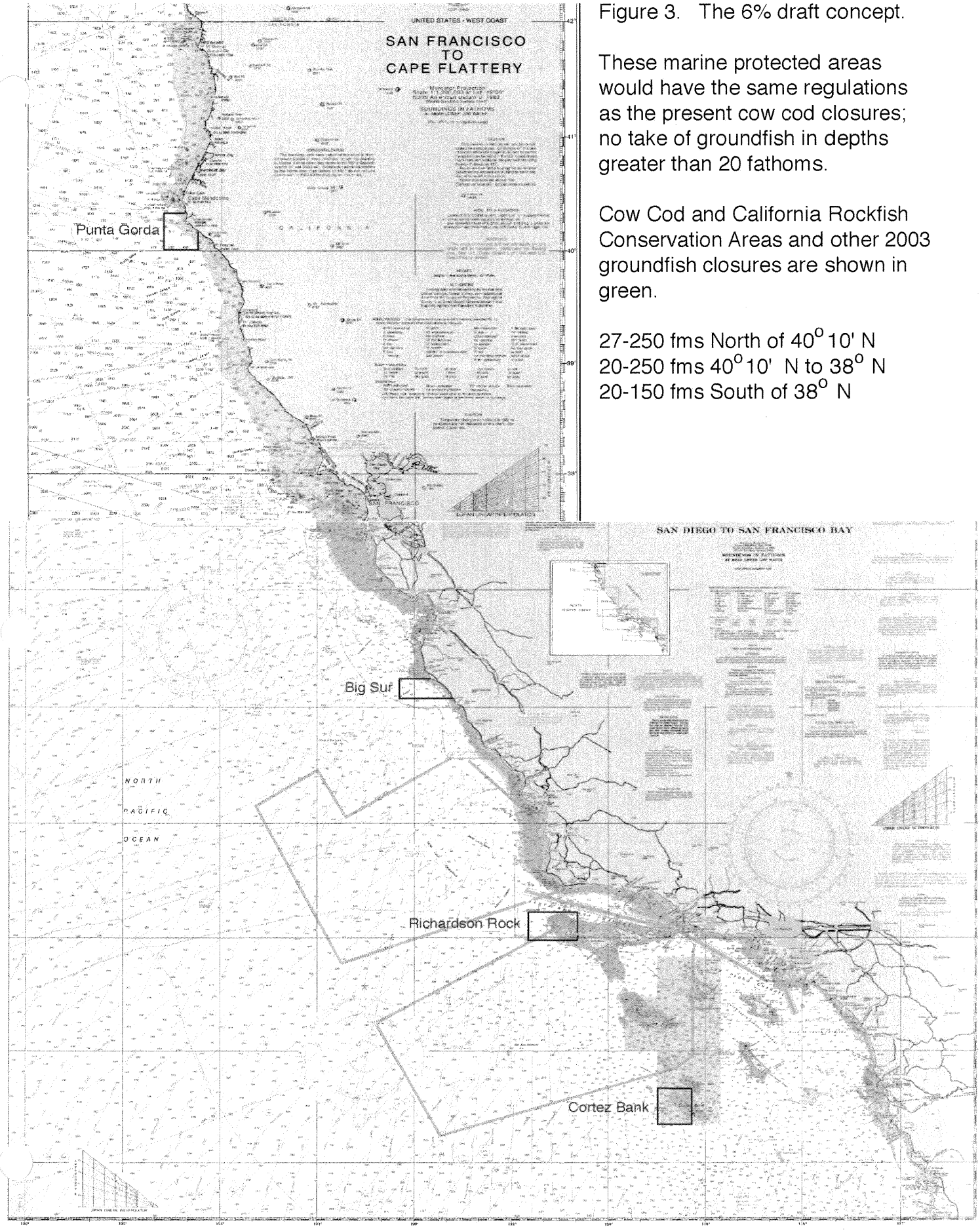


Figure 3. The 6% draft concept.

These marine protected areas would have the same regulations as the present cow cod closures; no take of groundfish in depths greater than 20 fathoms.

Cow Cod and California Rockfish Conservation Areas and other 2003 groundfish closures are shown in green.

27-250 fms North of 40° 10' N
20-250 fms 40° 10' N to 38° N
20-150 fms South of 38° N

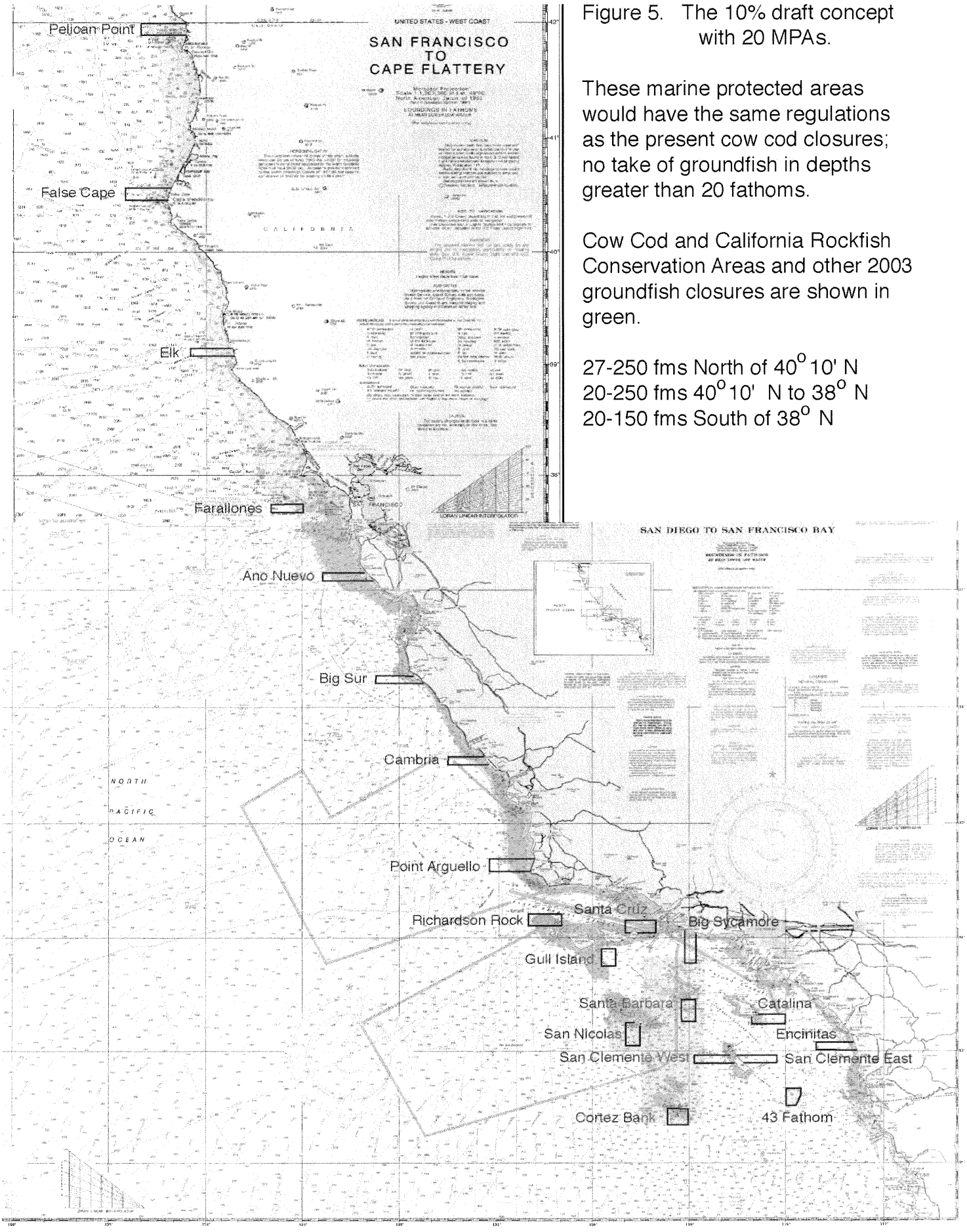


Figure 5. The 10% draft concept with 20 MPAs.

These marine protected areas would have the same regulations as the present cow cod closures; no take of groundfish in depths greater than 20 fathoms.

Cow Cod and California Rockfish Conservation Areas and other 2003 groundfish closures are shown in green.

27-250 fms North of 40° 10' N
20-250 fms 40° 10' N to 38° N
20-150 fms South of 38° N

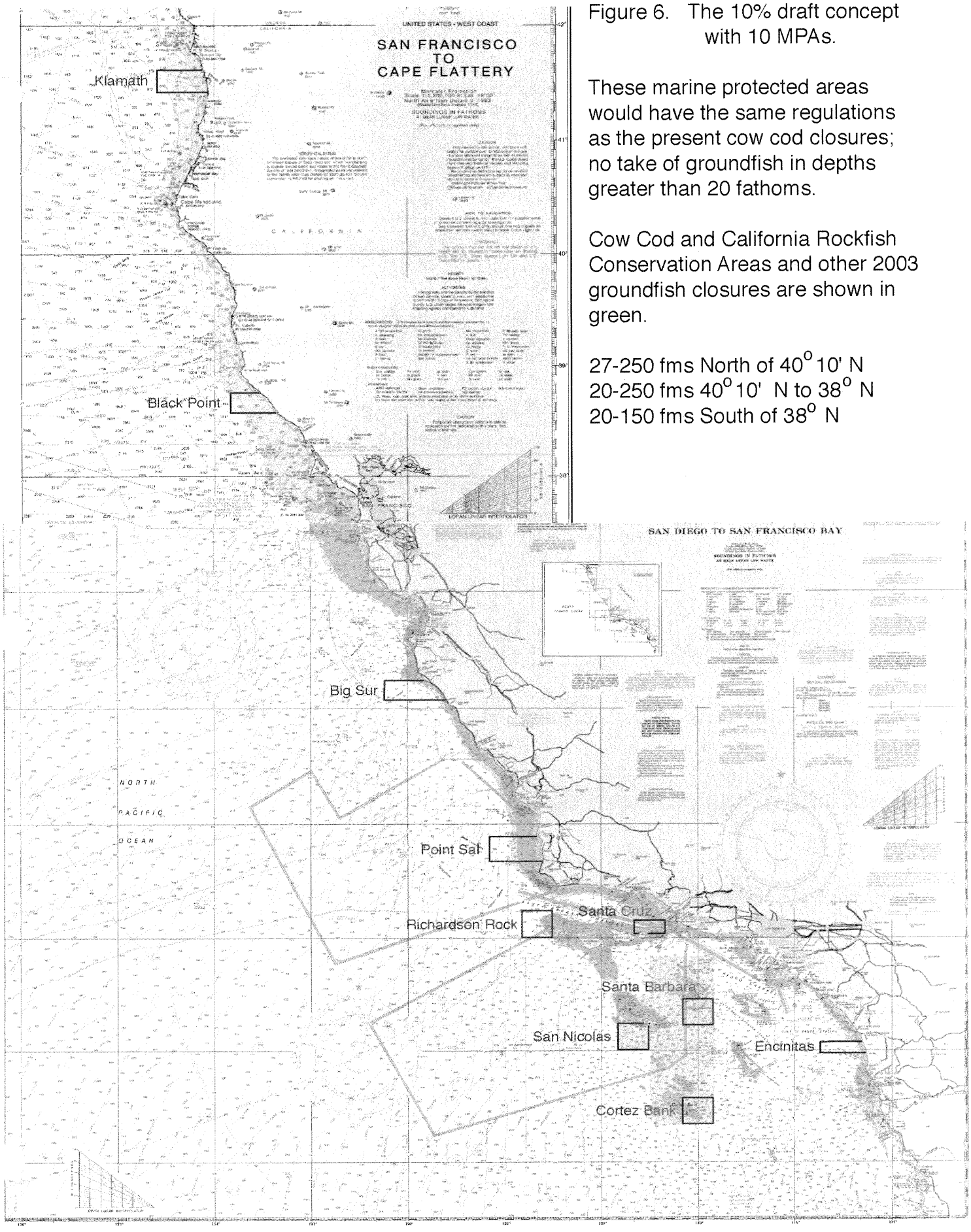


Figure 6. The 10% draft concept with 10 MPAs.

These marine protected areas would have the same regulations as the present cow cod closures; no take of groundfish in depths greater than 20 fathoms.

Cow Cod and California Rockfish Conservation Areas and other 2003 groundfish closures are shown in green.

27-250 fms North of 40° 10' N
20-250 fms 40° 10' N to 38° N
20-150 fms South of 38° N

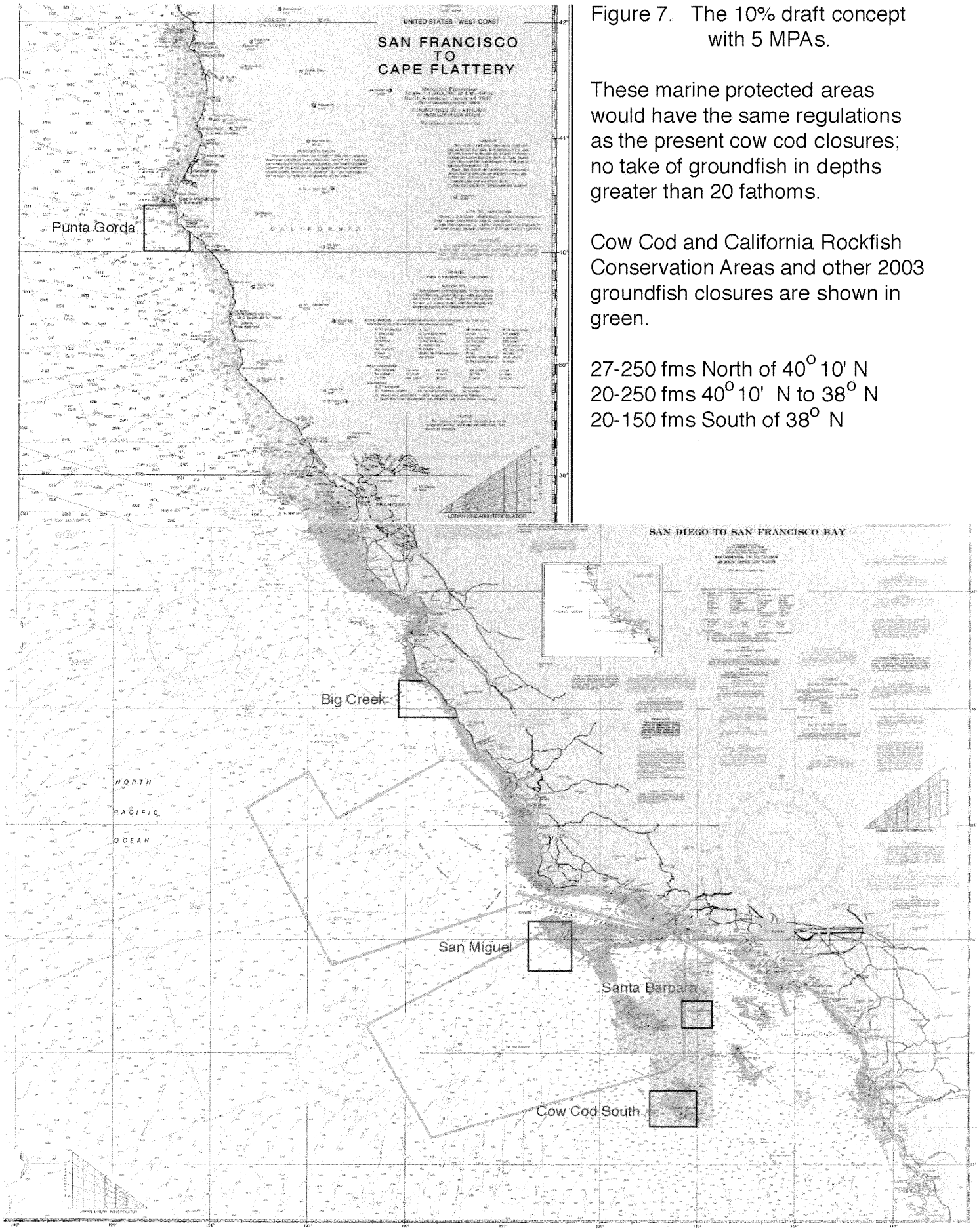


Figure 7. The 10% draft concept with 5 MPAs.

These marine protected areas would have the same regulations as the present cow cod closures; no take of groundfish in depths greater than 20 fathoms.

Cow Cod and California Rockfish Conservation Areas and other 2003 groundfish closures are shown in green.

27-250 fms North of 40^{o} 10' N
20-250 fms 40^{o} 10' N to 38^{o} N
20-150 fms South of 38^{o} N