# REPORT ON THE 2007 PACIFIC HALIBUT FISHERIES IN AREA 2A

(8/16/07)

The 2007 Area 2A total allowable catch (TAC) of 1,340,000 lb set by the International Pacific Halibut Commission (IPHC) was allocated as sub-TACs as follows:

| | |
|---|---|
| Treaty Tribes | 494,000 lb (35% + 25,000 lb) |
| Non-Tribal Total | 846,000 lb (65% - 25,000 lb) |
| Non-Tribal Commercial | 338,182 lb (includes incidental sablefish) |
| Washington Sport | 239,636 lb |
| Oregon/California Sport | 268,182 lb |

All weights in this report are net weight (gutted, head-off, and without ice and slime.) The structure of each fishery and the resulting harvests are described below.

## NON-TRIBAL COMMERCIAL FISHERIES

A sub-TAC of 338,182 lb (31.7% of the non-tribal share + 70,000 lb for the incidental sablefish fishery) was allocated to two fishery components: 1) a directed longline fishery targeting on halibut south of Point Chehalis, WA; and 2) an incidental catch fishery during the salmon troll fisheries off Washington, Oregon, and California. An additional 70,000 lb was allocated to an incidental catch fishery for limited entry, sablefish-endorsed vessels operating with longline gear north of Pt. Chehalis, WA. This allowance for the tiered sablefish fishery is only available in years when the overall Area 2A TAC exceeds 900,000 lb.

**Incidental halibut catch in the salmon troll fishery** A quota of 40,227 lb (15% of the non-Indian commercial fishery allocation) was allocated to the salmon troll fishery in Area 2A as an incidental catch during Chinook fisheries. According to the Catch Sharing Plan, the primary management objective for this fishery is to harvest the troll quota as an incidental catch during the May/June salmon troll fishery. If any of the allocation for this fishery remains after June 30, the fishery may continue to retain incidentally caught halibut in the salmon troll fisheries until the quota is taken. The final catch ratio established preseason by the Council at the April meeting was one halibut (minimum 32") per three Chinook landed by a salmon troller, except that one halibut could be landed without meeting the ratio requirement, and no more than 35 halibut could be landed per trip. Fishing with salmon troll gear is prohibited within the Salmon Troll Yelloweye Rockfish Conservation Area (YRCA) off the northern Washington Coast. Additionally, the "C-shaped" North Coast Recreational YRCA off Washington is designated as an area to be avoided (a voluntary closure) by salmon trollers.

- Halibut retention was permitted in the salmon troll fisheries beginning May 1. The quota for this fishery was revised to add the 3,440 lb remaining after the closure of the directed commercial fishery in August, for a revised quota of 43,667 lb. Of the halibut taken in the salmon troll fisheries through August 13, 7,965 lb were landed in Oregon and 13,384 lb were landed in Washington for a total of 21,349 lb.

**<u>Directed fishery targeting on halibut</u>** A quota of 227,955 lb (85% of the non-tribal commercial fishery allocation) was allocated to the directed longline fishery targeting on halibut in southern Washington, Oregon, and California. The fishery was confined to the area south of Subarea 2A-1 (south of Point Chehalis, WA; 46°53.30' N. lat.). In addition, between 46°53.30' N. lat. and 46°16' N. lat., the fishery was confined to an area seaward of a boundary line approximating the 100-fm depth contour and, between 46°16' N. lat. and 40°10' N. lat., to an area shoreward of a boundary line approximating the 30-fm depth contour and seaward of a boundary line approximating the 100-fm depth contour. One-day fishing periods of 10 hours in duration were scheduled by the IPHC for June 27, July 11, July 25, August 8, August 22, September 5, and September 19. A 32" minimum size limit with the head on was in effect for all openings. Vessel landing limits per fishing period based on vessel length were imposed by IPHC during all openings as shown in the following table. Vessels choosing to operate in this fishery could not land halibut in the incidental catch salmon troll fishery, nor operate in the recreational fishery.

**Fishing period limits (dressed weight, head-off in pounds) by vessel size.**

| Vessel Class/Size | 6/27 & 7/11 Opening | 7/25 Opening | 8/08 Opening |
|---|---|---|---|
| A 0 - 25 ft. | 755 lb | 380 lb | 250 lb |
| B 26 - 30 ft. | 945 lb | 475 lb | 315 lb |
| C 31 - 35 ft. | 1,510 lb | 755 lb | 505 lb |
| D 36 - 40 ft. | 4,165 lb | 2,085 lb | 1,390 lb |
| E 41 - 45 ft. | 4,480 lb | 2,240 lb | 1,495 lb |
| F 46 - 50 ft. | 5,365 lb | 2,680 lb | 1,790 lb |
| G 51 - 55 ft. | 5,985 lb | 2,995 lb | 1,995 lb |
| H 56+ ft. | 9,000 lb | 4,500 lb | 3,000 lb |

- The June 27 directed commercial fishery resulted in a catch of about 99,000 lb, leaving 128,918 lb for later openings.
- The July 11 directed commercial fishery resulted in a catch of 65,235 lb, leaving 63,608 lb for later openings.
- The July 25 directed commercial fishery resulted in a catch of 21,230 lb, leaving 42,378 lb for later openings.
- The August 8 directed commercial fishery resulted in a catch of about 38,938 lb, leaving 3,440 lb. The directed fishery closed and the remaining 3,440 lb was made available to the incidental halibut fishery during the salmon troll season.

**Incidental halibut catch in the primary sablefish longline fishery north of Point Chehalis** A quota of 70,000 lb was allocated to the limited entry primary sablefish fishery in Area 2A as an incidental catch during longline sablefish operations north of Point Chehalis, WA. The primary sablefish season is from April 1 to October 31, although incidental halibut retention was not available until May 1. Properly licensed vessels were permitted to retain up to 100 lb of dressed weight (headed-and gutted) halibut per 1,000 lb of dressed weight sablefish, plus up to two additional halibut per fishing trip. The fishery is confined to an area seaward of a boundary line approximating the 100-fm depth contour. Fishing is also prohibited in the North Coast Commercial YRCA, an area off the northern Washington coast. In addition, the "C-shaped" North Coast Recreational YRCA off Washington is designated as an area to be avoided (a voluntary closure) by commercial longline sablefish fishermen.

- Through August 13, this fishery is estimated to have taken 15,496 lb.

**SPORT FISHERIES (Non-tribal).**
A sub-TAC of 507,818 lb (68.3% of non-tribal share – 70,000 lb for the incidental sablefish fishery) was allocated between sport fisheries in the Washington area (47.2%) and Oregon/California (52.8%). The allocations were further subdivided as quotas among seven geographic subareas as described below.

**Washington Inside Waters Subarea** (Puget Sound and Straits of Juan de Fuca). This area was allocated 65,562 lb (27.4% of the Washington sport allocation). Due to inability to monitor the catch in this area inseason, a fixed season was established preseason based on projected catch per day and number of days to achieve the sub-quota. The Eastern Region (East of Low Point) opened on April 9 and continued through June 16, 5 days per week (Thursday-Monday). The Western Region opened on May 24 and continued through August 3, 5 days per week (Thursday-Monday). The daily bag limit was one halibut of any size per person.

- Landings data from this fishery are not yet available.

**Northern Washington Coastal Waters Subarea** (landings in Neah Bay and La Push). The coastal area off Cape Flattery to Queets River was allocated 116,199 lb (48.5% of the Washington sport allocation). The fishery was divided into two seasons with 32,536 lb set aside for the second season. The fishery was to open May 15 and continue 3 days per week (Tuesday, Thursday, and Saturday) until 83,663 lb were estimated to have been taken. The second season was to open on June 19 and 21 in the nearshore area only and on June 23 in all waters. If insufficient quota remains to reopen the entire north coast subarea on June 28, then the nearshore area would reopen on June 28, up to four days per week (Thursday-Sunday), until the overall quota of 116,199 lb are estimated to have been taken, or until September 30, whichever is earlier. The "C-shaped" North Coast Recreational YRCA, southwest of Cape Flattery, was closed to sport halibut fishing. The daily bag limit was one halibut of any size per person.

- The fishery opened May 15 and continued 3 days a week, through May 31, when 66,430 lb

were estimated to have been taken. The remaining quota for the May season, 17,233 lb, was not enough to continue the 3 day per week fishery; this remaining quota was transferred to the June season.
- The initial June season quota of 32,536 lb was revised to 49,769 lb. The season re-opened on June 19 and 21 in nearshore waters and June 23 in the entire subarea, during which days 20,977 lb were taken. Because there was enough quota remaining to reopen the entire subarea, the season has continued to be open for one day at a time on various days of the week in the entire subarea (June 28, July 7, July 22, and August 4). Through August 4, Washington North Coast sport fishery's June season is estimated to have taken 40,097 lb, leaving approximately 9,672 lb in the subarea quota.

**Washington South Coast Subarea** (landings in Westport). The area from the Queets River to Leadbetter Point was allocated 50,907 lb (21.2% of the Washington sport allocation). The fishery was to open on May 1 and continue 5 days per week (Sunday through Thursday) in all waters (primary fishery) and continue 7 days per week in waters between the Queets River and 47°25.00' N. lat. south to 46°58.00' N. lat., and east of 124°30.00' W. long. (northern nearshore fishery). The south coast subarea quota will be allocated as follows: 48,362 lb, 95 percent, for the primary fishery, and 2,545 lb, 5 percent, for the northern nearshore fishery, once the primary fishery has closed. The primary fishery will continue from May 1 until 48,362 lb are estimated to have been taken, or until September 30, whichever is earlier. Subsequent to this closure, if there is insufficient quota remaining to reopen the primary fishery for another fishing day, then any remaining quota may be used to accommodate incidental catch in the northern nearshore area on Fridays and Saturdays, until the entire subarea quota is projected to be taken. The daily bag limit was one halibut of any size per person.

- The 5 day per week primary fishery and the 7 day per week northern nearshore fishery opened on May 1 and remained open until May 8. The total catch for this subarea was 51,166 lb, exceeding the quota by 259 lb.

**Columbia River Subarea** (Leadbetter Point to Cape Falcon). This sport fishery subarea was allocated 20,378 lb, consisting of 2.0 percent of the first 130,845 lb allocated to the Washington sport fishery, 4.0 percent of the Washington sport allocation between 130,845 lb and 224,110 lb (minus the pounds needed for the incidental sablefish fishery), and 5.0 percent of the Oregon/California sport allocation or an amount equal to the contribution from the Washington sport allocation, whichever is greater. The fishery was to open May 1 and continue 7 days per week until 14,264 lb is estimated to have been taken or until July 15, whichever is earlier. The fishery was to reopen on August 3 and continue 3 days per week (Friday through Sunday) until the entire subarea quota has been taken or September 30, whichever is earlier. The daily bag limit was one halibut of any size per person.

- This 7 day per week fishery began on May 1 and closed on May 26 with a total catch of 14,071 lb.
- The fishery reopened August 3 and continued 3 days a week, through August 12, when 4,561 lb were estimated to have been taken, for a total of 18,632 lb. With 1,746 lb remaining in the

quota, this fishery reopened for 3 days on August 24, 25, and 26.

**Oregon Central Coast Subarea** (Cape Falcon to Humbug Mountain). This sport fishery subarea was allocated 246,727 lb (92% of the Oregon/California sport allocation less any amount needed to contribute to the Oregon portion of the Columbia River subarea quota).

Three seasons were set for this subarea: 1) a restricted depth (inside 40-fm) fishery to commence on May 1 and continue 7 days a week until October 31 or until the nearshore sub-quota of 19,738 lb were estimated to have been taken; 2) a fixed Spring season in all depths that was to open on May 10-12, 17-19, 24-26, May 31 – June 2, and June 7-9 with a catch allocation of 170,242 lb (the Spring season was to reopen for additional days if quota remains), and; 3) a Summer season in all depths that was to open on August 3-5, and which was to continue on as many weekends as possible until the total Spring-Summer quotas of 226,989 lb have been taken or until October 31, whichever is earlier. Additional fishing days may be opened if a certain amount of quota remained after August 5 and September 2, and/or an increase in the bag limit may be considered after September 2. The daily bag limit was one halibut of any size per person, unless otherwise specified.

- The inside 40-fathom fishery opened May 1 and is estimated to have taken 7,056 lb through August 12.
- The fixed Spring all-depth season in May-June, held May 10-12, 17-19, 24-26, May 31 – June 2, June 7-9, and, had a total catch of 104,385 lb, which left enough halibut in the quota to allow openings on June 21-23, July 5-7 and 19-21. During these nine additional spring all-depth fishery days, an additional 28,705 lb were taken. A total of 133,090 lb was taken in the Spring all-depth fishery, 37,152 lb under the Spring quota. The remaining Spring quota was added to the pounds available to the Summer all-depth fishery.
- The initial Summer all-depth season quota of 56,747 lb was revised by the 37,152 lb remaining from the Spring fishery. As a result, 93,899 lb was initially available to the Summer all-depth fishery. The Summer all-depth fishery opened on August 3-5 (Friday-Sunday). On August 8, NMFS, ODFW, and IPHC conferred inseason and took action to provide more fishing opportunity for the Summer all-depth fishery. The agencies agreed that because the remaining quota for the combined all-depth and inside 40-fm fishery was 94,707 lb (i.e., greater than 60,000 lb after August 5, as stated in the CSP and regulations), beginning August 10, the Summer all-depth fishery opened every Friday-Sunday. Through August 12, the fishery is estimated to have taken 23,711 lb.

**South of Humbug Mountain, Oregon and off the California Coast Subarea** This sport fishery was allocated 8,045 lb (3.0% of the Oregon/California quota). This area had a pre-set season of 7 days per week from May 1 to October 31 and a daily bag limit of one halibut of any size per person.

- This season is scheduled to remain open through October 31. No catch estimates are available for this fishery, but it is unlikely that this subarea quota will be taken.

## TRIBAL FISHERIES

A sub-TAC of 494,000 lb (35% + 25,000 lb of the Area 2A TAC) was allocated to tribal fisheries. The tribes estimated that 33,000 lb would be used for ceremonial and subsistence (C&S) fisheries and the remaining 461,000 lb were allocated to the commercial fishery. The 2007 management plan was essentially identical to the management plan that the tribes have had in place since 2004. This plan divides the fisheries into "separately managed" fisheries and "joint restricted" fisheries.

For the separately managed fisheries, a tribe or group of tribes was allocated a certain percentage of the TAC that could be harvested any time between noon on March 10 and noon on July 30. Collectively, the separately managed fisheries were allocated 75% of the Tribal Commercial TAC. The separately managed fisheries landed 350,394 lbs in 377 landings (out of 345,750 lbs expected).

The remaining 25% of the TAC was open to all parties in the "joint restricted" fishery. The joint restricted fishery opened at noon March 19 with a 500-lb/vessel/day limit and closed by mutual agreement at 11:59 pm on April 13 to assess total catch in that fishery. In order to try to achieve a 40-day opportunity, some tribes reopened their restricted fishery with the limit reduced to 200 lbs/vessel/day on April 18. Likewise, in order to provide greater opportunity to other participants, the Lummi Tribe's restricted fishery was closed during weekends and was only opened from March 19 to April 12. The restricted fishery was closed by all parties on May 3. The joint restricted fishery had a total catch of 118,042 lbs in 453 landings (out of 115,250 lbs expected).

| Fishery | Dates Held | Pounds Landed | # of Landings |
|---|---|---|---|
| Separately Managed | March 10 - July 30 | 350,394 lb | 377 landings |
| Restricted, 200-500 lb/vessel/day | March 19 – May 3 | 118,042 lb | 453 landings |
| Total | | 468,436 lb | 830 landings |

The C&S fishery will continue through December 31 and tribal estimates of catch will be reported by the tribes in January 2008.

| 2007 Area 2A TAC and Catch (in pounds) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Quota | | Inseason Revised Quota | | Catch | | Over/Under |
| TRIBAL INDIAN | 494,000 | | | | 501,436 | ✻ | 1.5% |
| Commercial | 461,000 | | | | 468,436 | | 1.6% |
| Ceremonial & Subsistence | 33,000 | | | | 33,000 | ✻ | -- |
| | | | | | | | |
| NON-TRIBAL | 846,000 | | | | 675,149 | ♠ | -20.2% |
| | | | | | | | |
| COMMERCIAL | 338,182 | | | | 261,360 | ♠ | -22.7% |
| Troll | 40,227 | | 43,667 | ♥ | 21,349 | ♠ | -51.1% of revised quota |
| Directed | 227,955 | | | | 224,515 | | -1.5% |
| Sablefish Incidental | 70,000 | | | | 15,496 | ♠ | -77.9% |
| | | | | | | | |
| SPORT | 507,818 | | | | 413,789 | ♠ | -18.5% |
| WA Sport | 239,636 | | | | 231,406 | ♠ | -3.4% |
| OR/CA Sport | 268,182 | | | | 182,383 | ♠ | -32.0% |
| | | | | | | | |
| WA Inside Waters | 65,562 | | | | 65,562 | ✻ ♠ | -- |
| WA North Coast | 116,199 | | | | 106,527 | ♠ | -8.3% |
| *May season* | 83,663 | | | | 66,430 | | -20.6% |
| *June season* | 32,536 | | 49,769 | ♣ | 40,097 | ♠ | -19.4% of revised quota |
| WA South Coast | 50,907 | | | | 51,166 | | 0.5% |
| | | | | | | | |
| Col River Area | 20,378 | | | | 18,632 | ♦ ♠ | -8.6% |
| *Early season* | 14,264 | | | | 14,071 | | -1.4% |
| *Late season* | 6,114 | | 6,307 | ■ | 4,561 | ♠ | -27.7% of revised quota |
| | | | | | | | |
| OR Central Coast | 246,727 | | | | 163,857 | ♠ | -33.6% |
| *Inside 40 fathoms* | 19,738 | | | | 7,056 | ♠ | -64.3% |
| *Spring (May-July)* | 170,242 | | | | 133,090 | | -21.8% |
| *Summer (August-October)* | 56,747 | | 93,899 | ★ | 23,711 | ♠ | -74.8% of revised quota |
| OR S. of Humbug/CA | 8,045 | | | | 8,045 | ✻ | -- |
| | | | | | | | |
| **TOTAL** | **1,340,000** | | | | **1,176,585** | ♠ | **-12.2%** |

✻ Assumed.

♥ The remaining 3,440 lb after the directed commercial fishery closed was rolled over to the halibut fishery that is incidental to the salmon troll fishery, increasing their quota to 43,667 lb.

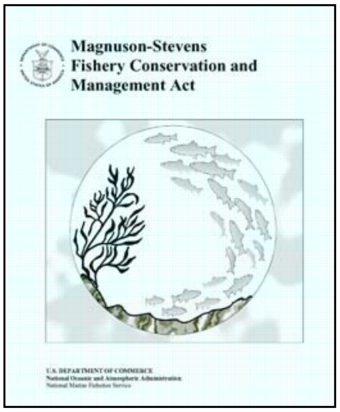
♣ Washington's North Coast May season fishery had 17,233 lb remaining after it was closed which was transferred to the June season, increasing the June quota to 49,769 lb.

■ The Columbia River Early season had 193 lb remaining after it was closed which was transferred to the Late season, increasing the Late season quota to 6,307 lb.

★ Oregon's Central Coast spring all-depth fishery had 37,152 lb remaining. This amount was transferred to the summer all-depth fishery, increasing that quota to 93,899 lb.

♠ Data from these fisheries not complete at the time of the briefing book deadline. Updates will be provided at the Council meeting, if available.

♦ Columbia River catch= 8,151 lb from WA + 10,481 lb from OR.




# Magnuson-Stevens Reauthorization Act: *Working Together on Implementation*

**Workshop September 25-26, 2007**
Washington, DC

*NOAA Fisheries Service (NMFS) in partnership with the Regional Fishery Management Councils is organizing a 2-day workshop on September 25-26, 2007, to help advance implementation of provisions in the Magnuson-Stevens Reauthorization Act (MSRA).*

❖ The objectives include:

1. Fostering an ongoing exchange of information on the implementation of new or expanded requirements included in the Act,
2. Understanding the required time frames, division of labor between Councils and NMFS, and revealing the intersections of the various mandates; and
3. Advancing strategies for fulfilling the requirements, identifying and resolving impediments to success, and offering priorities among competing options.

❖ The intended outcome is better informed and engaged stakeholders who have generated ideas and solutions on the best way forward for NMFS and the Councils on the issues covered.

❖ The target audience is stakeholders of MSRA implementation, including NMFS and the Councils, and industry and NGO representatives.

❖ The meeting will be held in Washington, DC in a workshop format: brief panel presentations on each of five issues followed by extensive table-top breakout sessions of small facilitated groups. To promote effective participant interaction and outcomes, attendance will be limited to 125 persons, principally by invitation.

❖ The preliminary list of five issues to be covered is:

1. Balancing Management Objectives: Capacity and Annual Catch Limits
2. Ecosystem-Based Management – Next Steps under MSRA?
3. Multispecies Management and Bycatch
4. International and Jointly Managed Fisheries
5. Aquaculture, Councils and Multi-Sector EEZ Activities

❖ The workshop planning is being led by the NMFS Office of Policy, utilizing a small steering committee of NMFS and Council personnel. For further information contact Dr. Mark Holliday, (301) 713.2239 or mark.holliday@noaa.gov.

Background/Context for Session Topics

The background/context for the preliminary list of five issues to be covered is described below. Each issue would be introduced by a brief panel presentation (1-2-3 or more panelists, one hour total to provide context and some Q&A, leading up to one to several trigger questions. This is to be followed by 2 to 2.5 hours of tabletop breakout sessions (e.g., on the Day one session (the biggest we'd have) ~10-12 tables of 10 persons; the remaining 4 topics on Day two would be 5-6 separate tables of 10 persons for each concurrent session, to focus on the trigger questions. Each table could deal with different questions, or the same one, depending on circumstances, and report-out back to the plenary on their results.

1. Balancing Management Objectives: Capacity and Annual Catch Limits
Session Organizer. Dr. Lee Anderson, University of DE/Mid-Atlantic Council Member
ACLs was the topic mentioned as the "elephant in the room" by almost everyone who was consulted. By the time of the workshop, a proposed rule on implementing the ACL provisions will have been published. Rather than focus on the nuts and bolts of the proposed rule and turn the workshop into a hearing or an on-the-administrative record rulemaking session, we propose to discuss some of the conceptual issues facing NMFS and Councils. ACLs are tools to achieve optimum yield and in the process prevent overfishing. However, given the most recent round of MSRA, how do we balance the biology and economics side of OY? For example, MSRA also asks us to report on overcapacity and identify prescriptions for removing excess capacity. In creating hard TACs/ACLs, we don't want to neglect the social and economic sides of achieving OY. Some questions to possibly consider:

What is the interplay of ACLs and LAPs? ACLs and buybacks?
What are relevant trade-offs between changes in risk and socioeconomic effects and how can they be considered?
What about other policies to help participants transition or at least to sign on to the rebuilding package?
How do we evaluate Accountability Measures (AMs) that are best for avoiding or mitigating overages?
Can buybacks, LAPs, and precautionary minimum spawning stock biomasses be considered AMs?
What role should the Council have in determining the level of capacity?
What role can/should LAPs play in achieving OY?
What role can/should buybacks play in achieving OY?
How are answers to the above questions changed in data poor or data weak fisheries?
How are answers changed in fisheries with mandated rebuilding plans?

2. Ecosystem-Based Management – Next Steps under MSRA?
Session Organizer: Dr. Dave Fluharty, University of WA
The Administration MSA bill placed a lot of emphasis on ecosystem approaches while the signed bill did not. What's in/out MSRA vs Admin bill – and what are the current challenges/opportunities re: new Section 406(f) and ecosystem approaches for Councils? What are Councils presently doing vs. present MSRA language, what are the results of pilot Council efforts? How do we transfer pilot projects to management actions? Integrated ecosystem assessments – what is the NOAA Science direction, can we agree on the scientific underpinnings necessary for policy choices? How do we encompass multi-sector EA mgt into existing

Regional Council fish governance model? How do we implement the joint MSRA provisions re: Deep sea corals?

3. Multispecies Management and Bycatch

Session Organizer: Lee Benaka, Office of Sustainable Fisheries

Section 316 of MSRA requires establishment of a bycatch reduction program, including grants, to develop technological devices and other conservation engineering changes designed to minimize bycatch, seabird interactions, bycatch mortality, and post-release mortality in federally managed fisheries. In addition, any fishery management plan prepared by a Council or by the Secretary may establish a system of incentives to reduce total bycatch and seabird interactions, amounts, bycatch rates, and post-release mortality in fisheries under the Council's or Secretary's jurisdiction.

How do they new requirements affect the standardized bycatch reporting methodologies?

What types of fisherman incentives will be effective?

How would individual bycatch quotas be assigned?

Can we best resolve multispecies mgt. issues across FMPS via conservation engineering?

4. International and Jointly Managed Fisheries

Session Organizer: Laura Cimo, Office of Policy

Passage of the MSRA has brought significant changes to the management of international and other jointly managed fisheries. The new requirements of MSRA – such as the establishment of annual catch limits and emphasis on bilateral/multilateral approaches and market-related measures to ending illegal, unregulated, and unreported (IUU) fishing and bycatch of protected living marine resources (LMRs) – bring a host of new challenges and potential opportunities for fisheries management. How will the management of international fisheries and other jointly managed fisheries change in light of new mandates to end overfishing? (*see language from Sec. 304(e) and Sec. 304(i))*

What are some common challenges with achieving rebuilding objectives in international and jointly managed state-federal fisheries, and how have these changed with passage of MSRA?

Are the new tools in MSRA to achieve our management objectives directly applicable in international and/or state-federal fisheries? If not, what other tools and authorizations are necessary or helpful?

What changes are necessary to emphasize bilateral/multilateral approaches and the use of market-related measures to ending IUU fishing and bycatch of protected LMRs in MSRA?

5. Aquaculture, Councils and Multi-Sector EEZ Activities

Session Organizer: Wayne Swingle, Gulf of Mexico Fishery Management Council

The Gulf Council is going to public hearings this July on their aquaculture amendment requiring EEZ permits; the SA Council recently adopted an aquaculture policy statement, other Councils may be actively doing things as well, all with the overlay of the House and Senate aquaculture bills that have been introduced. The FMP amendment may be approved prior to any national legislation. Is there a consistent EEZ approach Councils should develop (how would it be subject to state law/possible opt-out interactions)? How should fishery enhancement via aquaculture play into stock rebuilding and ACLs? What should be the role of Councils in permitting aquaculture or any other non-fishing (other sector) EEZ activity that impacts EFH or sustainability of LMRs? What follow-up from the aquaculture summit impacts Councils?

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE
Monterey Bay National Marine Sanctuary
299 Foam Street
Monterey, California 93940

July 26, 2007

Dear Marine Protected Areas Working Group Member:

As you know, for the last five years the Monterey Bay National Marine Sanctuary's (Sanctuary) MPA working group has been meeting to discuss the potential for new MPAs in federal waters of the Sanctuary. We appreciate the time and effort you have given to this process. Your input has been invaluable. We have made significant progress in implementing the action plan that the working group created. This includes identifying conservation goals, compiling data, developing support tools, and analyzing particular areas of interest. Perhaps most importantly, the members of the group have gained an understanding and appreciation for the expertise and the perspectives of the others at the table. We are now however, at the point where additional progress will require further guidance, more focused discussion, and ultimately a decision on the need for MPAs in federal waters.

To date, we have focused on resource and use evaluations, which was where meaningful progress could be made. These discussions educated us all on Sanctuary habitats, resources, use patterns, and the role MPAs may play in achieving Sanctuary goals. At the last meeting in April, you were given a chance to draw on that knowledge and state your own conclusions regarding the need for new MPAs in the federal waters of the Sanctuary. That input was highly valued, but it underscored the fact that agreement on the need for MPAs in the Sanctuary is probably unattainable. In order for us to reach a conclusion on this important issue, we will be reviewing your past input and considering the possible need for additional information.

Over the next two months, we will schedule separate meetings with the working group constituents, the fishing community, environmental groups, and the science community to discuss the issue of the need for MPAs in the federal waters of the Sanctuary. We recognize that some may not feel that they fit into one of these groups and we will work to ensure that we hear these additional perspectives as well. In addition, I will be asking the Sanctuary Advisory Council (SAC) for advice on this issue during a two-day meeting in early December.

The first day of the December SAC meeting will be largely devoted to the SAC receiving input from the MPA working group members on the need for MPAs. We encourage those presenting to the SAC at this meeting to discuss the need for MPAs in the context of the National Marine Sanctuaries Act and the MPA working group's goals. The SAC will be asked to provide its advice to the Sanctuary on the second day of the meeting. In order to facilitate SAC discussion and advice, we ask that a written summary of working group member presentations be available to circulate 10 days prior to the meeting.

With the benefit of the work conducted over the last five years, stakeholder presentations, and the SAC's advice, we will reach a decision on the need for MPAs in the federal waters of the Sanctuary. We hope to present this decision at the February SAC meeting. Should we conclude that there is a need for MPAs, the SAC will be asked for advice regarding next steps.

We will contact each of you to discuss the details of this approach and to address questions and concerns that you may have. We appreciate the contributions that each of you have made during this process and ask for your continued participation and thoughtful input. Should you have any questions please contact Huff McGonigal at 831-647-4254.

Sincerely,

Paul Michel
Superintendent

cc: Sanctuary Advisory Council Members

PERSPECTIVE:
FISHERIES MANAGEMENT

**Robert C. Francis**
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# Ten Commandments for Ecosystem-Based Fisheries Scientists

**ABSTRACT:** In an effort to accelerate the ongoing paradigm shift in fisheries science from the traditional single-species mindset toward more ecosystem-based approaches, we offer the following "commandments" as action items for bridging the gap between general principles and specific methodologies.

1. Keep a perspective that is holistic, risk-averse, and adaptive.
2. Question key assumptions, no matter how basic.
3. Maintain old-growth age structure in fish populations.
4. Characterize and maintain the natural spatial structure of fish stocks.
5. Characterize and maintain viable fish habitats.
6. Characterize and maintain ecosystem resilience.
7. Identify and maintain critical food web connections.
8. Account for ecosystem change through time.
9. Account for evolutionary change caused by fishing.
10. Implement an approach that is integrated, interdisciplinary, and inclusive.

Although the shift in worldview embodied in these commandments can occur immediately without additional funding, full implementation of ecosystem-based fisheries science will require an expanded empirical basis as well as novel approaches to modeling. We believe that pursuing these action items is essential for productive marine fisheries to become truly sustainable for present and future generations.

## Diez preceptos para científicos pesqueros que aplican el enfoque ecosistémico

**RESUMEN:** Tratando de acelerar el cambio entre los paradigmas de manejo pesquero de un enfoque convencional que considera la evaluación de una sola especie a otro que toma en cuenta a todo el ecosistema, nosotros proponemos los siguientes preceptos como elementos que contribuyan a tender un puente entre los principios generales y las metodologías específicas de ambas posiciones:

1. Considerar una perspectiva hiolística, precautoria y adaptativa.
2. Examinar cuestiones clave, no importa que tan básicas sean.
3. Conservar las estructuras poblacionales de edad y crecimiento.
4. Caracterizar y conservar y la distribución espacial de los stocks.
5. Caracterizar y conservar los hábitats viables.
6. Conocer y conservar la resiliencia de los ecosistemas.
7. Identificar y conservar las conexiones críticas del las tramas tróficas.
8. Registrar temporalmente los cambios del ecosistema.
9. Registrar los cambios evolutivos causados por la pesca.
10. Proponer sistemas de manejo integrales, interdisciplinarios e incluyentes.

Si bien el cambio general de perspectiva derivada de estos preceptos puede ocurrir inmediatamente, la implementación total del manejo pesquero a partir de un enfoque ecosistémico requiere ampliar la base empírica y el desarrollo de nuevas herramientas de modelación. Consideramos que el cumplir con los elementos enumerados anteriormente es fundamental para que las pesquerías marinas sean verdaderamente sustentables ales entre los temas e impactos de los torneos y se sugiere que los efectos de los torneos no varían entre las diferentes tipos de pesquería. Comparando estos resultados con un estudio previo se observa que la problemática y los beneficios asociados al desarrollo de los torneos han cambiado de 1989 a la fecha; los temas sociales siguen siendo relevantes, pero los impactos biológicos se consideraron como de poca importancia. Las agencias reconocen que los torneos pueden mejorar el manejo de las pesquerías y el reclutamiento de los pescadores. Para la planeación de los futuros torneos debe considerarse un trabajo más integral.

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Who in blazes are we to have the audacity to issue 10 commandments? Well, we certainly do not believe that we are Yahweh et al. Rather, because you are reading this, we suspect that the title grabbed you, and so our goal regarding this outrageously grandiose heading is fulfilled. In reality, our humble intention is to stimulate much needed discussion regarding the explicit details of ecosystem-based fisheries science as a bonafide new discipline. We perceive a need to bridge the gap between general principles, which are already well-articulated, and specific methodologies for full implementation, which is the present challenge and beyond the scope of this article. Our intention is to help ecosystem-based fisheries science escape the danger of becoming either "quasi-religious" (sensu Larkin 1996:149) or "surreal" (sensu Longhurst 2006:108) by proposing tangible action items. Given our collective backgrounds, we address only the natural sciences, yet emphasize the need for ecosystem-based management to integrate the natural and social sciences (see Commandment 10).

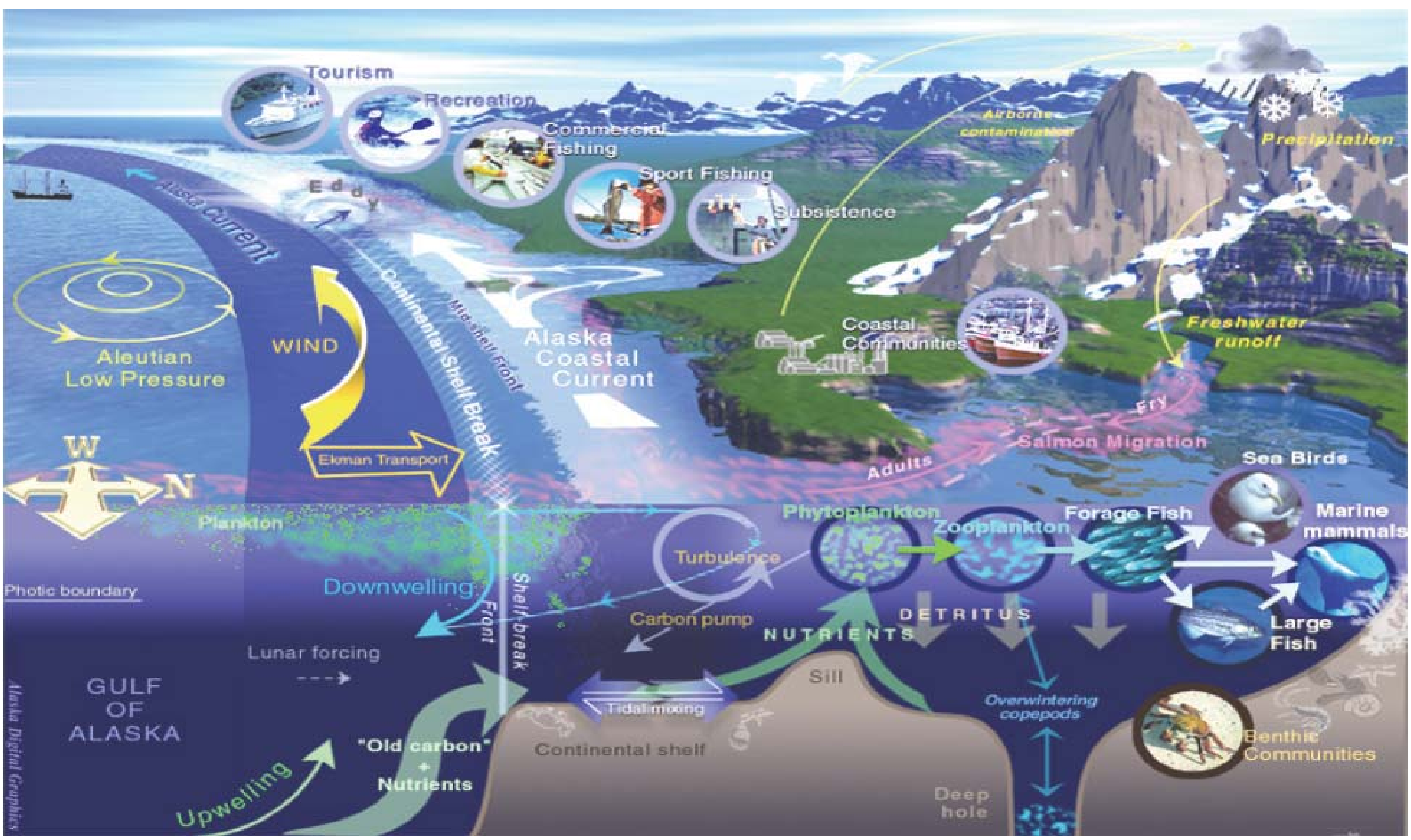
Although a marine "ecosystem" is a human construct that artificially delineates a portion of the ocean, and given that the biosphere comprises highly integrated linkage of all such systems, we are content using definitions proposed by NOAA (2005:3) in the context of this article: "An ecosystem is a geographically specified system of organisms, including humans, the environment, and the processes that control its dynamics. An ecosystem approach to management is management that is adaptive, specified geographically, takes into account ecosystem knowledge and uncertainties, considers multiple external influences, and strives to balance diverse social objectives."

The ongoing transition in fisheries management from a traditional single-species focus toward ecosystem-based approaches has many characteristics of a classic Kuhnian "paradigm shift." According to Kuhn (1962), during the course of a scientific revolution, an established worldview is replaced by another set of fundamental assumptions. Typically, more progressive, open-minded, and often younger practitioners of the new paradigm face substantial resistance from entrenched defenders of the status quo. We personally have witnessed such resistance toward ecosystem-based management by some fisheries scientists, the same professionals who are the primary purveyors of science for management decisions. However, the paradigm shift in fisheries science is not entirely Kuhnian because the ongoing transition toward ecosystem-based approaches has been more evolutionary than revolutionary, and no one to our knowledge is advocating the complete abandonment of traditional fisheries biology.

Despite some resistance toward ecosystem-based approaches, single-species fisheries science and management is increasingly seen as necessary yet insufficient, and often ineffective for maintaining catches that are both productive and sustainable ("sustainable" in both the modern and post-modern sense of Quinn and Collie 2005, but see Longhurst 2006). This problem is especially evident where bycatch is substantial, where bottom gear impacts seafloor habitats, where fisheries exploit multiple species simultaneously, and when various assumptions of traditional single-species approaches are violated (Browman and Stergiou 2004 and included papers). There is ample evidence that many marine fishery stocks are not managed sustainably, even those subjected to rigorous scientific scrutiny (Hilborn et al. 2003). Worldwide, an estimated 25% of major stocks are over-exploited, depleted, or recovering from depletion, 52% are fully exploited, and 23% are under or moderately exploited (FAO 2006; see also Mullon et al. 2005). Some practitioners are gravely concerned that only about a quarter of the stocks are clearly healthy (e.g., Jennings 2004), whereas others are content that only a quarter of the stocks are depleted or otherwise over-exploited (e.g., Mace 2004). Regardless of whether one sees the glass as three-quarters empty or three-quarters full, and despite the fact that traditional fisheries biology has been adequate in some systems (Hilborn 2005), more effective approaches to fisheries science seem prudent.

Although ecosystem-based fishery concepts have existed for many years (e.g., Sette 1943; Iles 1980), and have been implemented in some regions for some time (e.g., Murawski et al. 2000; Witherell et al. 2000), critics of traditional management have only recently pressed for a more holistic scientific approach that incorporates the ecosystem context of fisheries into management policy (e.g.,

**Commandment 1.** The Gulf of Alaska from a holistic ecosystem perspective (NOAA Fisheries Service).



Botsford et al. 1997; Pikitch et al. 2004; USCOP 2004; Field and Francis 2006). To date, most publications on ecosystem-based management have focused on broad principles (e.g., Ecosystem Principles Advisory Panel 1999; NRC 1999; Gislason et al. 2000; Coleman and Travis 2002; Link 2002a; Barange 2003; Francis 2003; Rose and Cowan 2003; Browman and Stergiou 2004, 2005; Walters and Coleman 2004; Guerry 2005; McLeod et al. 2005).

Beyond useful compendia of ecosystem-based management guidelines (e.g., Larkin 1996; Link 2002b; Fowler 2003; Walters and Martell 2004; Garcia and Cochrane 2005; NRC 2006), there has been no definitive exploration of explicit action items for a full transition to what we call "ecosystem-based fisheries science" (EBFS). We believe that EBFS should not replace traditional fisheries biology per se, but rather that conventional single-species approaches should be incorporated into the broader and ecologically more realistic discipline of EBFS. In an effort to clarify the essential components of EBFS and to address the important question posed by Frid et al. (2006) regarding advances in natural science required for ecosystem-based management, we offer the following 10 commandments to both the revolutionaries and the reactionaries in this ongoing paradigm shift. Although these action items are general in nature, most examples are drawn from the California Current Ecosystem, with which most of us have the greatest experience.

## COMMANDMENT 1: *Keep a perspective that is holistic, risk-averse, and adaptive*.

> *Out of context, the best minds do the worst damage.*
>
> —Wes Jackson (Berry 2005:45)

This fundamental commandment provides the necessary worldview and general context for all that follows. For us, EBFS is more an issue of context and mindset than of method (and thus does not require vast quantities of additional data and funding). Berry (2005:42) says this regarding context in modern agriculture:

> *It is no longer possible to deny that context exists and is an issue. If you can keep the context narrow enough (and the accounting period short enough), then the industrial criteria of labor saving and high productivity seem to work well. But the old rules of ecological coherence and of community life have remained in effect. The costs of ignoring them have accumulated, until now the boundaries of our reductive and mechanical explanations have collapsed.*

Walters and Kitchell (2001) point out that over the past half century, context has changed in marine fisheries as well. They argue that there have been three important steps in the evolution of the theory of fishing. The first two focused on abundance of individual single-species stocks and the direct effects of exploitation on stock productivity, respectively. The third step—focus on ecological interactions—has become necessary with recent severe stock depletions and their unexpected or unknown ecosystem consequences, rendering some single-species techniques either unreliable or unsatisfactory when considered in isolation (e.g., Longhurst 1998; Pauly et al. 1998; Bundy 2001; Jackson et al. 2001). As a result, fishery resource managers are confronted with increasingly complex issues—issues characteristically involving tradeoffs and interactions within and between nature and society.

With this in mind, we believe that Field and Francis (2006:552) provide a useful basis for characterizing EBFS and, in particular, the role of the biological sciences in its implementation:

> *A common theme is that such an ecosystem approach involves a more holistic view of managing resources in the context of their environment than presently exists. For marine fisheries management, this must include taking into greater consideration the constantly changing climate-driven physical and biological interactions in the ecosystem, the trophic relationships between fished and unfished elements of the food web, the adaptation potential of life history diversity, and the role of humans as both predators and competitors. Recognizing that all management decisions have impacts on the ecosystem being exploited, an ecosystem-based approach to management seeks to better inform these decisions with knowledge of ecosystem structure, processes and functions.*

Recently there has been a serious attempt to join the concept of sustainability with the growing scientific understanding that both human and natural systems are complex and adaptive (Holling 2001). Holling and Meffe (1995) made the point that science and policy are inextricably linked when it comes to natural resource issues. What they call "command and control" policy—reduce system variability and make the system more predictable—is based on a "first-stream" scientific view of natural and social systems that concentrates on stability near an equilibrium steady-state. Clearly, the concept of maximum sustainable yield (MSY) falls into this realm. An alternative basis for natural resource policy, what Holling and Meffe call "golden rule" policy—retain or restore critical types and ranges of natural and social variation, and facilitate existing processes and variability—is based on a "second-stream" scientific view of natural and social systems that concentrates on conditions far from any equilibrium. In this case, instabilities can flip a system into another regime of behavior (see Commandments 2, 6, 7, and 8). Developed by Holling and colleagues, these concepts have formed the basis for the integrated concept of "social-ecological systems" (Berkes et al. 2003), and a new field of sustainability science that seeks to understand the fundamental character of interactions between nature and society (Kates et al. 2001; Hughes et al. 2005).

Once fisheries are viewed from such a holistic perspective, then ecosystem-based fisheries science necessarily becomes both risk-averse and adaptive. The biosphere is so complex that we will never have sufficient information to understand ecosystems completely. At the same time, those who dismiss the ecosystem approach as being too data-hungry miss the point. Fishery science will always be severely data-limited and uncertainty will always be high (Walters and Martell 2004). As such, the onus is on fishery scientists to encourage implementation of risk-averse management approaches that set fishing quotas, gear restrictions, and fishing zones in ways that are relatively conservative compared to traditional approaches.

There are two major incarnations of risk-averse decision making, also characterized as the so-called precautionary principle. First, quoting the United Nations Food and Agricultural Organization's "Code of Conduct for Responsible

Fisheries" (FAO 1995:5): "The absence of adequate scientific information should not be used as a reason for postponing or failing to take measures to conserve target species, associated or dependent species, and non-target species and their environment." Second, Dayton (1998) describes reversal of the burden of proof, involving a shift in perspective from risk-prone type I error (e.g., increasing exploitation rates until it is demonstrated that those rates have negative effects on a stock) to risk-averse type II error (e.g., not increasing exploitation rates until it has been demonstrated that negative effects are unlikely). Fundamentally, this shift requires nothing more than sound judgment, derived from a holistic appreciation that fisheries systems are complex beyond our immediate grasp. Approaches for implementing the precautionary approach are detailed in the following commandments (see also González-Laxe 2005).

Hand-in-hand with a precautionary approach is the adaptive approach, which calls for learning by doing in the face of incomplete knowledge. As originally proposed by Holling (1978) and refined by Lee (1993), adaptive management treats economic uses of nature as experiments, so that we may learn efficiently from experience. As Lee (1993:9) says, "Linking science and human purpose, adaptive management serves as a compass for us to use in searching for a sustainable future." Of particular importance to this discussion, adaptive management is ecosystem-based rather than based solely on jurisdictional criteria, and operates on a time scale that is biologically driven. In the context of adaptive management, ecosystem-based fisheries scientists should encourage implementation of management policies that test hypotheses regarding sustainable fisheries in a cycle of informed trial-and-error (Walters and Hilborn 1976; Walters 1986). Modeling plays a central role in this approach, both in generating hypotheses and synthesizing information (Latour et al. 2003; Walters and Martell 2004). Lee (1993) gives an excellent example of an attempt at adaptive management regarding salmon enhancement in British Columbia.

## COMMANDMENT 2: *Question key assumptions, no matter how basic.*

*Here lies the concept, MSY.*
*It advocated yields too high.*

—Peter Larkin (1977:10)

This is a critical commandment for any kind of science, but is particularly true for science which is advisory to fishery management decisions. For example, the most common and sophisticated single-species stock assessment models often assume that: (1) recruitment is solely a function of spawning biomass; (2) natural mortality is constant over the time frame of stock assessment; (3) unexploited biomass is constant; (4) if exploitation ceases, the stock biomass will rebuild to that unexploited level due to endogenous density-dependent mechanisms; and (5) for any given level of fishing effort, stock biomass will approach an equilibrium at which it will remain in perpetuity. Now the question is not whether these assumptions are actually true, but whether making these assumptions affects the integrity of the stock assessment. Consider documented violations of each assumption:

1. Recruitment of many marine fish stocks appears to depend as much on stock structure (e.g., spatial distribution, age structure) as on cumulative stock biomass (Berkeley et al. 2004b).
2. Natural mortality can be highly variable in time and space (Sogard 1997), and constant values used in stock-assessment models often have little or no empirical basis (Vetter 1988). Walters (2000) argues that whole-ecosystem processes (e.g., food web dynamics) can have profound effects on individual stock processes, such as natural mortality and the nature of recruitment.
3. If one takes the best estimate of highly variable recruitment from a recent stock assessment of Pacific hake (*Merluccius productus*) and simply runs an unexploited version of the stock assessment model over that trajectory, estimated unexploited stock biomass will vary considerably. One might then ask what the concept of constant unexploited biomass ($B_o$) means in this case. Additionally, increasing evidence indicates that density dependence in at least demersal (seafloor-associated) marine fishes is largely caused exogenously by predation rather than endogenously by competition (Hixon and Jones 2005). Accordingly, a more modern view of MSY and its associated biomass ($B_{MSY}$) is as a dynamic equilibrium incorporating natural variability in recruitment and survivorship, and potentially incorporating biological interactions if they can be quantified (Mace 2001).
4. The collapse of fisheries for northern cod (Bundy 2001; Haedrich and Hamilton 2000, Longhurst 1998) and West Coast rockfish (Ralston 1998; Gunderson 1984; Levin et al. 2006) clearly show the incapacities of marine ecosystems to "rewind" from overfishing. When marine ecosystems are contorted enough by exogenous factors, thresholds are passed and the rules of organization change. Not only are new stability domains created, but also reversibility (i.e., stock rebuilding) is no longer a meaningful assumption.
5. The cases of Pacific hake (above) and Bristol Bay sockeye salmon (*Oncorhynchus nerka;* Hilborn et al. 2003) suggest that stocks may have no long term equilibrium behavior.

Once again, any scientific assessment requires making assumptions about the way nature works. The important point is to be explicit about those assumptions and question them within the context of the particular issue being addressed.

Walters et al. (2005) have used ecosystem models to show that widespread application of the contemporary (MSY-proxy) single-species management approach could lead to dramatic impacts on ecosystem structure, particularly where such approaches are applied to forage species. The lesson is that fisheries scientists should exercise caution in recommending MSY policy based on single-species assessments that ignore the ecosystem roles of exploited species. There are at least two perspectives on coping with this issue, both of which are held by different authors of this article. One is to view MSY as an evolving and viable paradigm that has not always been implemented properly in the past, but is nonetheless essential in fisheries science (Mace 2001, 2004). The other is to replace MSY with a more holistic "ecologically sustainable yield" (ESY) (Zabel et al. 2003). The concept of ESY could include a variety of indicators (Froese 2004), including

1. Percentage of mature fish in the catch, with the target approaching 100%;
2. Percent of fish near optimum length in the catch, with the target approaching 100%; and

3. Percentage of "big, old, fat female" spawners in the catch (see Berkeley et al. 2004b), with the target approaching 0%.

## COMMANDMENT 3:
## *Maintain old-growth age structure in fish populations.*

*Logic surely demands that a fishery for a species having intermittent recruitment must somehow eschew the common practice of truncating the age structure.*

—Alan Longhurst (2002:6)

Recent (and even not so recent) studies belie three implicit assumptions of traditional fisheries biology regarding spawning females of relatively long-lived species. The first assumption is that all eggs are identical, and in particular, that eggs from younger smaller females and older larger females are equivalent (Beverton and Holt 1957). This notion has persisted despite early evidence that larger females produce larger eggs (Nikolsky 1953). Recent experiments on Pacific rockfish (genus *Sebastes*) have demonstrated that older females produce eggs with larger oil droplets, resulting in larvae that both grow faster and survive starvation better than larvae from younger females (Berkeley et al. 2004a). Such maternal effects are evident in a variety of fish species (reviews by Chambers and Leggett 1996; Heath and Blouw 1998; Berkeley et al. 2004b; Berkeley 2006; Longhurst 2006).

The second assumption of traditional fisheries biology is that all mature females are equivalent in terms of spawning behavior. They often are not. In a broad range of marine fishes, older females spawn earlier and may have more protracted spawning seasons than younger females (Berkeley and Houde 1978; Pederson 1984; Lambert 1987; Berkeley et al. 2004b). In environments where larval food production and larval drift vary either seasonally or in unpredictable ways, fish that spawn at the wrong time or place will not contribute to the new cohort because their larvae will perish. Off Oregon, older female black rockfish (*Sebastes melanops*) spawn earlier than younger females (Bobko and Berkeley 2004), and in some years are responsible for producing most of the new cohort despite the fact that older females comprise a small fraction of the spawning stock (Bobko 2002). Similar patterns are


**Commandment 3.** Big (44 in), old (ca.100 y), fat (60 lb.), fecund female shortraker rockfish (*Sebastes borealis*) taken off Alaska (Karna McKinney, Alaska Fisheries Science Center, NOAA Fisheries Service).

evident in Icelandic cod (*Gadus morhua*; Marteinsdottir and Thorarrisson 1998) and North Sea haddock (*Melanogrammus aeglefinus*; Wright and Gibb 2005).

The third assumption is that long-lived individuals per se are not essential for an exploited stock to persist. In reality, the evolution of long life spans with repeated spawning (iteroparity) is now recognized as a bet-hedging response to variable environments where larval survival and successful recruitment may be uncommon (Leaman and Beamish 1984; Longhurst 2002, 2006; Hsieh et al. 2006). Long-lived spawners thus provide a "storage effect" whereby a stock will persist as long as enough adults outlive periods unfavorable to successful spawning and recruitment (Warner and Chesson 1985). This pattern is expected to be particularly important at the margins of species ranges, where successful recruitment is often rare (MacCall 1996). Additionally, age-related differences in the time and location of spawning (Berkeley and Houde 1978; Lambert 1987; Hutchings and Myers 1993) may spread larval production in a way that accounts for temporal and spatial variability in larval environments. Indeed, there is genetic evidence that Hedgecock's (1994a,b) "sweepstakes hypothesis" occurs in West Coast rockfishes (review by Berkeley et al. 2004b; see also Field and Ralston 2005). Available data indicate that each new cohort is the product of a small fraction of all spawners, and that this small group of successful spawners changes both spatially and temporally due to unpredictable variation in larval environments.

The fact that traditional fishery biology often subsumes these considerations indicates that the age and size structure of a stock are likely as important as the magnitude of its spawning biomass in providing sustainable catches (Berkeley et al. 2004b; Beamish et al. 2006). The obvious conclusion is the need to minimize what has conventionally been seen as an expected and harmless side-effect of fishing to maximize density-dependent surplus production: age and size truncation (the loss of older age classes and larger size classes). Such alteration of population structure is prevalent among many fishery species (e.g., for the West Coast, see Harvey et al. 2006; Levin et al. 2006) and is now seen as leading to "longevity overfishing" (Beamish et al. 2006; Hsieh et al. 2006).

Old-growth age structure can be maintained by three approaches (Berkeley et al. 2004b):

1. Lowering catch rates substantially, which can be economically infeasible;
2. Implementing slot limits (release of both small and large individuals), which is often impossible due to capture mortality (e.g., via swimbladder expansion); and
3. Implementing marine protected areas (MPAs) to ensure that at least part of the stock can reach old age and large size.

Berkeley (2006) has modeled these scenarios and concluded that, for species similar to rockfishes, utilizing MPAs may provide the greatest fishery yields. At the very least, ecosystem-based fisheries scientists should monitor age and size structure, and incorporate these considerations into stock assessments.

## COMMANDMENT 4: *Characterize and maintain the natural spatial structure of fish stocks.*

> *Broad spatial distribution of spawning and recruitment is at least as important as spawning biomass in maintaining long-term sustainable population levels.*
>
> —Steven Berkeley et al. (2004b:23)

Traditional fisheries biology was founded on the assumption of unit stocks: regionally interbreeding populations that are reproductively closed (Cushing 1968; Pitcher and Hart 1982). In modern parlance, a stock is actually a "metapopulation" comprising local populations linked by larval dispersal (Kritzer and Sale 2004), rather than the older and often false assumption of a larger, spatially discrete and reproductively isolated population (reviews by Frank and Leggett 1994; Field and Ralston 2005). Recent genetic and otolith microchemical studies indicate that marine stocks have complex spatial structures at much smaller scales than previously assumed (reviews by Laikre et al. 2005; Gunderson and Vetter 2006). For example, most of some 60 species of rockfish (*Sebastes*) are assessed as single stocks along the entire Washington-Oregon-California coast of the United States. Yet, recent genetic analyses show substantial geographical discontinuities that indicate multiple, isolated stocks along this coastline (Rocha-Olivares and Vetter 1999; Buonaccorsi et al. 2002, 2004, 2005; Cope 2004; Miller and Shanks 2004; Gomez-Uchida and Banks 2005; Hawkins et al. 2005; Miller et al. 2005).

The important implication of these findings is that a decline in fish abundance in one region may not be replenished quickly or inevitably from another region. Thus, averaging stock assessments among regions may result in localized overfishing. Management fallout from this scenario is that the fishing community in one region may be unfairly penalized for overfishing that occurs in another, ecologically distinct region.

How can this dilemma be avoided? In short, the artificial spatial scale of stock assessment and management must better align with the natural spatial scale of target populations. Each managed species should be screened for stock subdivision using now well-developed and reasonably-priced genetic and otolith approaches. We anticipate that ecological regions will emerge where stock boundaries of particular groups of species are coincident. Until such analyses are completed, and as the first approximation in an adaptive process, initial subdivisions could be based on well-documented biogeographic boundaries, such as the series of large capes along the U.S. West Coast. Such ecologically-based regions should initially define the spatial units of stock assessment and management, rather than the arbitrary political regions presently used. Eventually, new data will allow delineation of actual metapopulation boundaries.

If present management regions, such as the entire U.S. West Coast, are subdivided into so many ecologically-based regions that multiple stock assessments as traditionally implemented become prohibitively expensive, then more robust and less data intensive approaches should be implemented to assure stock sustainability and ecosystem integrity (see Froese 2004). These approaches include less aggressive catch quotas, as well as use of novel tools to ensure stock viability, such as marine protected areas (NRC 2001; Ward et al. 2001; Shipley 2004; Sobel and Dahlgren 2004). In any case, continuing to rely on traditional stock assessments that either ignore or artificially delineate the true spatial structure of fish populations is clearly a recipe for disaster.

## COMMANDMENT 5:
***Characterize and maintain viable fish habitats.***

*No habitat, no fish—*
*it's as simple as that.*

—ANONYMOUS

Within the biogeographical region inhabited by a particular stock, the types of fish habitats and their spatial distributions must also be incorporated into fisheries science if sustainability is to be ensured (Benaka 1999; Coleman and Travis 2000). Seafloor mapping and fish habitat characterization over broad spatial scales is now a reality (Barnes and Thomas 2005 and included papers). Until Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (HAPC) were incorporated as part of fisheries management law in the United States, there was little focus on habitat by traditional fisheries biology. An ecosystem-based approach includes identification of nursery habitats, spawning sites, and other areas required to maintain stock integrity, and protection of those areas from bottom-gear impacts and other deleterious activities (NRC 2001, 2002). Importantly, much seafloor habitat is biogenic, created by corals, kelps, seagrasses, and other structure-forming organisms, so protection of fisheries habitat is truly equivalent to conserving the biodiversity of seafloors (see Kaiser et al. 2002, 2006). Additionally, stock assessments of demersal species should take into account the fact that the seafloor is heterogeneous, thereby increasing the accuracy of assessments via integration of spatially explicit population sampling with seafloor habitat mapping (Nasby-Lucas et al. 2002; NRC 2004). In short, ecosystem-based fisheries science is inherently place-based at multiple spatial scales.

## COMMANDMENT 6:
***Characterize and maintain ecosystem resilience.***

*Even though the scientists on a team*
*may be world-class experts in their*
*respective component fields, they are*
*all likely to be amateurs when it comes*
*to the system as a whole.*

—CRAIG NICHOLSON ET AL. (2002:383)

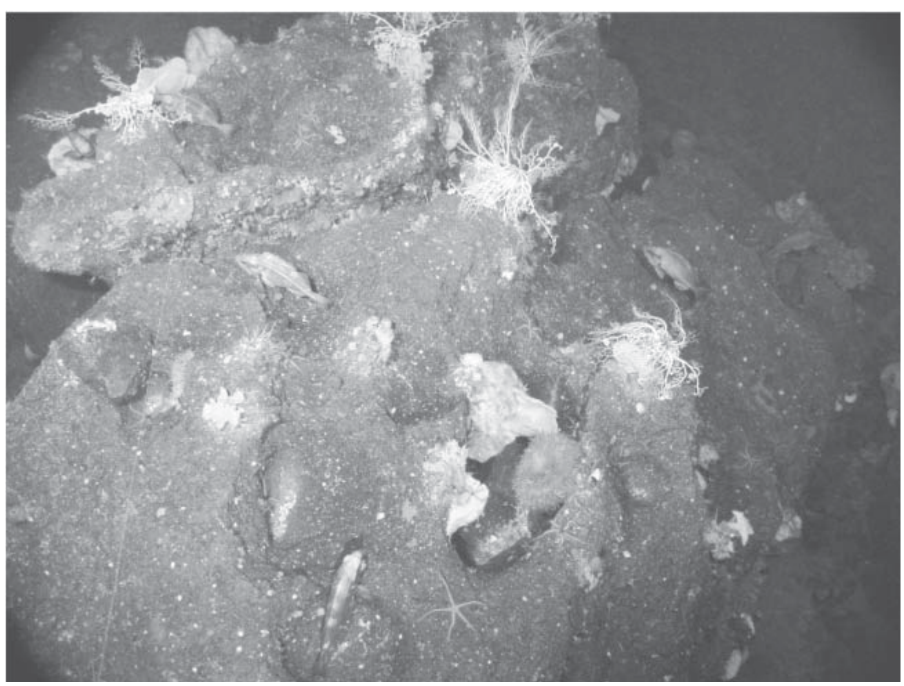
The science of both ecological and social systems has undergone a major conceptual change in the past few decades—the recognition that nature is seldom linear (the rules of organization can change) and often unpredictable (Berkes et al. 2003). The concept of "resilience" is a useful scoping device for integrating ecosystem and social system complexity. This concept originated in ecology and has been applied and studied primarily in the context of non-human systems. However, there have recently been attempts to apply the concept in the broader context of social-ecological systems (Levin et al. 1998; Berkes et al. 2003). Taking the narrower line and focusing on natural ecosystems, "resilience" is defined as "the extent to which ecosystems can absorb recurrent natural and human perturbations and continue to regenerate without slowly degrading or unexpectedly flipping into alternate states" (Hughes et al. 2005:380). Walker et al. (2004) describe four crucial components of resilience (see also Gunderson 2000):

1. **Latitude:** the maximum amount a system can be changed before losing its ability to recover;
2. **Resistance:** the ease or difficulty of changing the system;
3. **Precariousness:** how close the current state of the system is to a limit or threshold; and
4. **Panarchy:** dependence of the focal system on processes occurring and scales above and below (influence of cross-scale interactions).

The first three components define the capacity of an ecosystem to maintain its current rules of organization. Since food webs comprise the fundamental organizing relationships in ecosystems (Paine 1980), these first three components really refer to the nature of the stability domain of the existing food web—how broad is it, how resistant is it to change, and how close is the current food web to reorganizing. Gaichas (2006) and Little et al. (personal communication School of Aquatic and Fishery Sciences, University of Washington, Seattle, Washington) attempt to quantify these first three components with regard to the Gulf of Alaska and Northern California Current coastal marine ecosystems, respectively.

The final component of resilience, panarchy, refers to the cross-scale effects that can occur in both space and time. Climate change is a perfect example of a major marine ecosystem perturbation that is occurring at very different temporal and spatial scales than those that previously dominated the structure and function of most marine fishery ecosystems, and yet has a huge potential impact on ecosystem resilience (see Commandment 8). A sec-

**Commandment 5.** Bank rockfish (*Sebastes rufus*) and basket stars live at 200-m depth on a rocky seafloor at Cherry Bank off California (Northwest Fisheries Science Center, NOAA Fisheries Service).



ond example of panarchy is metapopulation structure manifested as a complex network of source and sink populations with vast spatial reach (Frank and Leggett 1994). Field and Ralston (2005) describe an example of this phenomenon regarding rockfish in the California Current system.

And so, within the context of an ecosystem as a complex adaptive system (Levin 1998), there are two looming questions that must eventually be addressed by ecosystem-based fisheries scientists:

1. How is ecosystem resilience created and maintained in exploited systems?
2. How can this understanding be translated into fishery management policy?

Evolving ecosystem indicators will provide useful tools for monitoring resilience (reviews by Cury and Christensen 2005; Jennings 2005). In any case, the emerging paradigm is one in which marine biodiversity per se at the genetic, population, and ecosystem level is valued by fisheries science as an essential requisite for the resilience of fisheries (Hughes et al. 2005). This recognition underscores the importance of monitoring bycatch and other collateral loss of sea life during fishing activities and minimizing that loss via gear modifications and marine protected areas (Crowder and Murawski 1998; Lewison et al. 2004). It also indicates the value of marine reserves for enhancing resilience by ensuring that at least portions of ecosystems remain relatively intact (NRC 2001).

## COMMANDMENT 7: *Identify and maintain critical food-web connections.*

> *To keep every cog and wheel is the first precaution of intelligent tinkering.*
>
> —Aldo Leopold (1953:146)

The structure of an ecosystem is defined by relationships, and food webs create the fundamental organizing relationships in ecosystems (Paine 1980), especially in the context of fisheries (Mangel and Levin 2005). From this point of view, one of the most important tasks of EBFS is to understand food web relationships, and subsequently use them to form a context for setting fishery management policy. Mathematical modeling is an imperfect but useful tool for exploring the consequences of various fishery management policies. And if we want to explore complex interactions and tradeoffs, we are almost forced to use some kind of mathematical model. Walters and Martell (2004:xix) put it this way:

> *[Fisheries] management is a process of making choices. There is no way to make choices without making at least some predictions about the comparative outcomes of the choices, and these predictions cannot be made without some sort of "model" for how the world works.*

And thus, like it or not, to the extent that food-web processes affect ecosystem resilience and fishery productivity, they need to be better understood and incorporated into stock-assessment and management models. Of course, models have their limits in terms of their abilities to represent complex adaptive dynamics.

The words of Levin (1998:433) certainly ring true in this regard: "All ecosystems are complex adaptive systems, governed by similar thermodynamic principles and local selection." Yes, the laws of thermodynamics are universal and do apply. And it is those laws that serve as a basis for the way we model ecosystems. However, the ocean environment is highly variable. The heat of the sun, spin of the Earth, and structure of the ocean basins create an ever-changing mosaic of marine habitats—a mosaic that, over deep time, has guided the evolution and organization of life in so many different directions. On top of that, ecosystems are non-linear—their rules of interaction change as the system evolves.

And so, what evidence do we have that, in fact, food web processes affect ecosystem resilience and fishery production? And what actions can we take to begin to further understand these patterns and mediate management concerns?

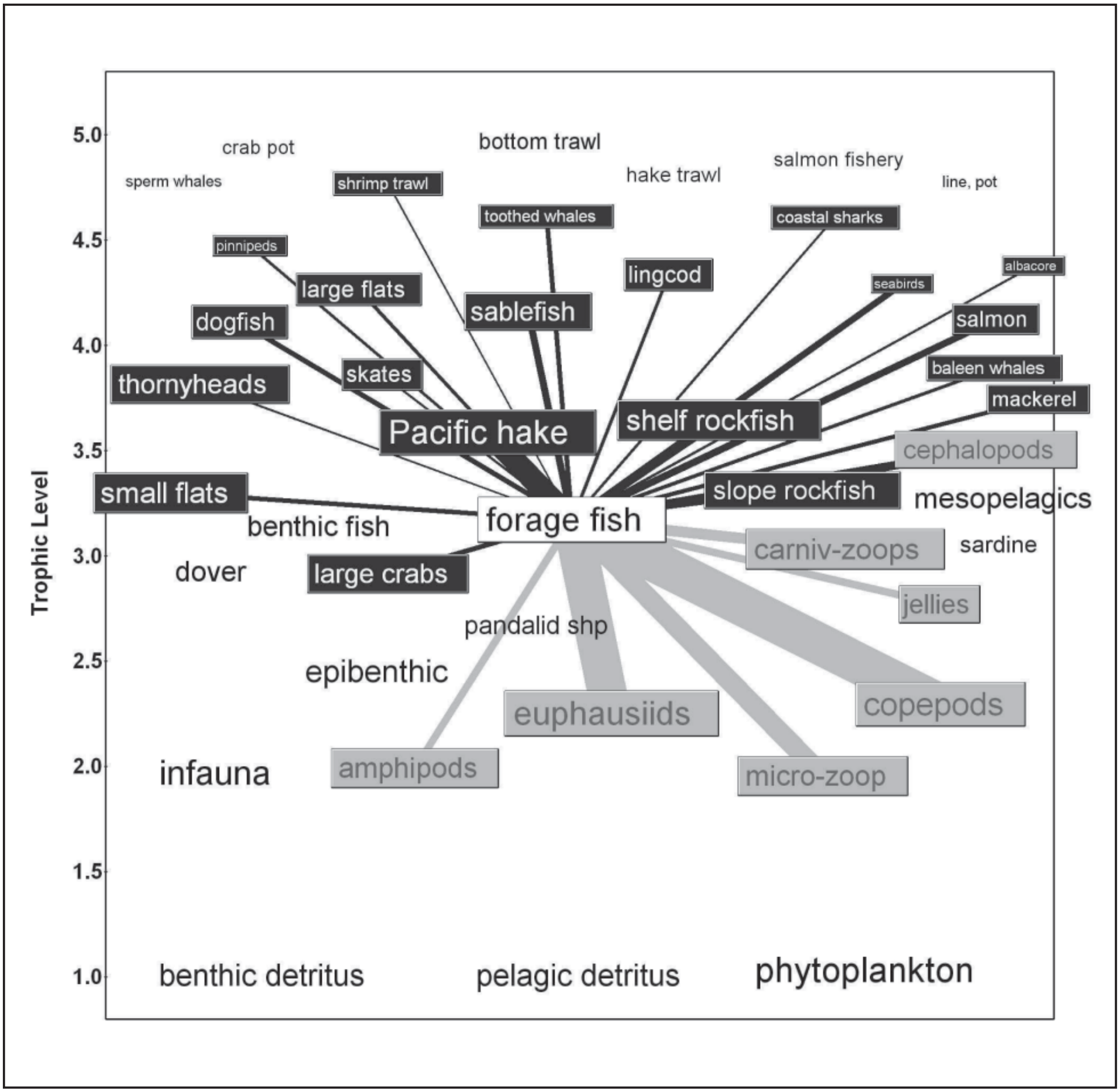
1. **Northern cod collapse.** A model of the Newfoundland-Labrador ecosystem (Bundy 2001) suggested that although overfishing drove massive declines in northern cod abundance, cod recovery was likely hindered by top-down food web processes. This seems to be a concrete example of the existence of ecological feedbacks such as cultivation-depensation (Walters and Kitchell 2001). In addition, the model suggested that declines in cod and several other heavily fished species may have resulted in increases in commercially valuable invertebrates. This example suggests that the entire single-species concept of overfishing and recovery needs to be readdressed in an ecosystem context. This conclusion overlaps with Commandment 2 by questioning key assumptions of conventional fisheries biology and the whole concept of recovery from overfishing.
2. **Alaska ecosystem reorganization**. Springer et al. (2003) present a convincing argument that the sequential collapse of four northeastern Pacific marine mammal species (northern fur seal, harbor seal, Steller sea lion, and sea otter) in recent decades was caused by increased predation (top-down forcing) which resulted from altered food-web dynamics brought about by the post-World War II decimation of the great whales of the region. They postulate that the extremely rapid reduction of whale biomass profoundly altered the workings of the ecosystem, in terms of both predation by baleen whales on zooplankton and forage fish, and predation by killer whales on great whales. A combination of population-matrix and bioenergetic models was used to support the robustness of their inference. Their conclusion is that commercial whaling in the North Pacific set-off one of the longest (half-century) and most complex ecological chain reactions ever described. This example suggests that exploiting species with strong connections to forage organisms could trigger severe and long-term ecosystem shifts. Additionally, it points out the potential top-down effects of large-scale and rapid removals. Both these lessons indicate that ecosystem-based fisheries scientists would do well to recommend avoidance of such activities.
3. **Fishing-induced trophic cascade on Scotian Shelf.** Frank et al. (2005) documented long-term dramatic shifts in the Scotian Shelf ecosystem caused by the overfishing of northern cod and other large predatory fishes (see also Scheffer et al. 2005). The demise of these top predators caused increases in the abundance of their prey (including small fishes and shrimp), which in turn resulted in declines of their prey (large-bodied zooplankton), which in turn caused increases in the abundance of their prey (phytoplankton), which ultimately resulted in declines in nitrate utilized by the phytoplankton, a classic

trophic cascade. As in previous examples, this case suggests the importance of an ecosystem perspective in developing the concept of overfishing (see Murawski 2000; Little et al. personal communication).

4. **Northern California Current ecosystem and climate.** Field et al. (2006) showed that climate can affect ecosystem productivity and dynamics both from the bottom-up (through short- and long-term variability in primary and secondary production) as well as from the top-down (through variability in the abundance and spatial distribution of key predators). Incorporating both top-down and bottom-up effects of climate forcing into an Ecosim model for the Northern California Current significantly improved the performance of the model over a 40+ year historical time series. This pattern certainly shows the controlling influence that climate has on a major predator like Pacific hake (*Merluccius productus*). Clearly, fisheries scientists recommending harvest policy on such species should keep this example in mind.

Echoing the ramifications of Com-

**Commandment 7.** The central and crucial role of various forage fish (mostly clupeids and osmerids) in the northern California Current food web during the 1990s. Black boxes are predators of these forage fish and gray boxes are their prey, including very small cephalopods. Boxes are positioned by mean trophic level and sized by log-scaled standing-crop biomass. Trophic lines are scaled by biomass flow from prey to predator (John Field and Kerim Aydin).



mandment 6, such case studies underscore the importance of maintaining the integrity and biodiversity of marine ecosystems, not only obviously important top predators and forage species, but also the entire the food web on which fishery species depend. In this sense, it is imperative to keep in mind that target populations not only may be regulated and stabilized by their predators and competitors (review by Hixon and Jones 2005), but also may in turn affect the populations and biodiversity of their prey (review by Hixon 1986).

## COMMANDMENT 8:
***Account for ecosystem change through time.***

> *Nothing is permanent but change.*
> —Heraclitus

The issue of time presents itself to fishery scientists in at least two ways. First, it challenges the conventional scientific method in terms of our inability to predict the behavior of complex adaptive systems. And second, it stretches the traditional time domain of management in terms of the effects of the physical climate on ecosystem structure and dynamics. Consider each of these issues in turn:

**Scientific method.** Clearly ecosystem structure unfolds in time and this happens at a vast number of scales. Carpenter (2002) points out that the range of turnover times in ecosystems spans at least 12 orders of magnitude, from the split-second generations of bacteria to the millennial generations of redwoods. In order to operationalize the concept of the ecosystem in the context of resource management, we must allow our thinking to range from evolutionary time (Levin 1998) to sudden interannual shifts in ecosystem organization (Hughes 1994).

Folke et al. (2004) point out the importance of slow changing variables in structuring ecosystem resilience. Examples include long-term shifts in marine ecosystems induced by exploitation (see Commandment 7). Carpenter (2002:2070) describes "the long now" as a way of connecting the past, present, and future of ecosystems. What he strives for is a way to look forward in a way informed by the past:

> *The ecology of the long now helps us understand how present ecosystem states came to be, how present decisions impact future ecosystems, and how systems of people and nature might be perpetuated.*

Of particular importance is the idea that prediction has very limited use when dealing with ecosystems, because in order to predict for a given time horizon, one must treat slow variables as parameters (constants). And with the exception of very limited time horizons:

> *The future dynamics of ecosystems are contingent on drivers that are outside the domain of ecology, such as climate change, human demography, or globalization of trade. The probability distribution of ecological predictions depends in part on the distributions of such drivers, but future driver distributions may be unknown or unknowable. Therefore the uncertainty of the ecological prediction cannot be calculated.*

And so, how do we examine the future under such constraints on prediction? Carpenter (2002) proposes scenarios—narratives of plausible futures consistent with ecological understanding and their estimated probabilities based on current knowledge. Perhaps, most importantly, is the point that "scenarios encourage action whereas uncertainties sometimes lead to doubt, inaction, and further analysis" (Carpenter 2002:2080). Scenarios provide a context for the future by stimulating broad thinking. Bundy (2001) used a model of the Newfoundland-Labrador ecosystem and fishery to explore scenarios for observed ecosystem responses after cessation of fishing in the early 1990s (e.g., failure of cod to recover, increases in snow crab and shrimp fisheries). Little et al. (pers. comm.) used a similar model of the Northern California Current ecosystem and fishery to develop scenarios for both short-term and long-term interactions and feedbacks between fleet and ecosystem structures.

**Physical climate.** Climate variability clearly has a huge impact on the structure and dynamics of marine ecosystems. Focusing on the California Current coastal marine ecosystem as an example, the effects of climate on the biota of the ecosystem have long been known (e.g., Hubbs 1948; Chelton et al. 1982). Currently the El Niño/Southern Oscillation (ENSO) is widely recognized to be the dominant mode of interannual variability in the equatorial Pacific, with impacts throughout the rest of the Pacific basin and globe (Mann and Lazier 2006). In addition to interannual variability in ocean conditions, the North Pacific seems to exhibit substantial interdecadal variability (Francis et al. 1998). Mantua et al. (1997) first described what is now commonly referred to as the Pacific (inter) Decadal Oscillation (PDO) which is defined technically as the leading principal component of North Pacific (N of 20° N) sea surface temperature between 1900-1993. Numerous studies have shown links between these two climate processes and biological production in the California Current (e.g., McGowan et al. 1998, Peterson and Schwing 2003, Peterson and Keister 2003 for zooplankton; Hare et al. 1999, Logerwell et al. 2003 for salmon; Field and Ralston 2005 for rockfish recruitment; Field et al. 2006, Little et al. personal communication for the Northern California Current Ecosystem).

Processes we have come to think of as cyclic are really evolutionary when examined at the appropriate time scale. Using proxy records from trees and corals, Gedalof et al. (2002) indicate that the PDO does not appear to have been a robust feature of North Pacific climate variability over the past two centuries. Whereas it had a strong interdecadal signature during the twentieth century (Mantua et al. 1997), it had a much reduced influence during the nineteenth century. Recent studies have questioned whether the PDO continues to be the dominant mode of interdecadal variability in North Pacific climate (Bond et al. 2003; Goericke et al. 2005).

Beyond recognized cyclical variation, the world oceans are now changing directionally into unknown territory due to global climate change, including increasing ocean acidity (reviews by Orr et al. 2005; Roessig et al. 2004; Harley et al. 2006). Despite denial in nonscientific circles, it is now obvious that the oceans are warming (Levitus et al. 2000; Hansen et al. 2005) and the scientific consensus regarding this fact is equally clear (Oreskes 2004; IPCC 2007). A major effect of ocean warming is ongoing poleward shifts in the geographic distributions of fishery species (Perry et al. 2005), as well as species of plankton (Hays et al. 2005), benthos (Barry et al. 1995), and marine diseases (Harvell et al. 1999). Models additionally predict that upwelling patterns, and thus the distribution and abundance of productive fisheries, could shift dramatically (Bakun 1990; Diffenbaugh et al. 2004). Indeed, spatial patterns of primary production in the North Atlantic (Richardson and Schoeman 2004) and secondary production in the Southern Ocean (Atkinson et al. 2004) are already changing detectably. Additionally, the frequency of cyclical events, such as El Niño conditions, is predicted to increase (Timmermann et al. 1999). In the Pacific, Paya (2005) and Field (personal communication, NOAA Fisheries Service Southwest Fisheries Science Center, Santa Cruz, California) report a recent poleward range expansion of jumbo squid (*Dosidicus gigas*) into waters off Chile and California, respectively, with potentially profound effects on food webs (e.g., consumption of hake in both systems). Paya (2005) estimates that squid predation has decimated the Chilean hake biomass from 1.2 million to 300,000 metric tons in 2 years.

Such ongoing and predicted shifts indicate the need for ecosystem-based fishery scientists to monitor at least the boundaries and characteristics of stocks through time, and in any case, to implement both precautionary and adaptive approaches to address unpredictable directional change in fishery systems. In any case, what is true today may very well not be so tomorrow.

The degree to which long-term climate change is affecting the world's oceans and their ecosystems relative to other forms of variability is currently a major concern, and the consequent interactions among monotonic (global warming), interdecadal (PDO), and interannual (ENSO) climate variability are difficult to disentangle. The bottom line is that climate variability and change have major impacts on coastal marine ecosystems and their fisheries, and so any ecosystem-based fishery science must attempt to take these phenomena into account despite ever-growing uncertainty. The first step would be to reject any notion that we have the capacity to fine-tune allowable biological catches to the razor edge of MSY (Schrank 2007). Rather, the risk-averse approach to MSY is to set targets with sufficient margins of error to reflect variations in life history and recruitment of target species, ocean productivity, and errors in estimation and implementation. Perhaps MSY would be more realistically characterized as a time-dependent variable ($MSY_t$). Additionally, marine reserves could serve as reference sites to help disentangle the local effects of fishing from the global effects of human activities (NRC 2001).

## COMMANDMENT 9:
***Account for evolutionary change caused by fishing.***

> *Yet ultimately the success for fishery management may be judged not by the catch achieved in any given year or decade, but by whether it was sustained across future generations.*
> —David Conover (2000:306)

Traditional fisheries biology has not fully recognized the potential of fishing mortality to cause directional selection in fish populations (reviews by Frank and Leggett 1994; Conover 2000; Hutchings 2000; Law 2000; Stokes and Law 2000; Walters 2000; Law and Stokes 2005; Longhurst 2006). A truly ecosystem-based fisheries scientist takes a Darwinian perspective of how fishing affects fish populations, acknowledging that most fisheries are selective by their very nature, and therefore comprise large-scale uncontrolled manipulations of life-history evolution via artificial selection (Rijnsdorp 1993). More generally, we believe that ecosystem-based management—that broader context now being forced on us by history and the law of consequences—is essentially the incorporation of more holistic evolutionary and ecological principles into natural resource management.

Selective fishing-induced mortality affects previously unfished populations by, first, reducing absolute fitness within the population (i.e., decreasing the proportional frequency of genotypes between generations), and second, changing the relative fitness of genotypes that code for different life histories within the population (Conover 2000). There are two specific issues regarding documentation of these effects (Stokes and Law 2000): (1) whether there is genetic variation for traits selected by fishing, and (2) how strong the selection caused by fishing is. Available evidence suggests that heritabilities of traits affected by fishing are large enough to lead to observable evolution over mere decades of fishing. There is also ample evidence that large phenotypic changes have occurred in major fish stocks due to differentially targeting larger and older size and age classes (i.e., size and age truncation), including reduction in length and age at maturation and overall reduction in size-at-age (reviews by Stokes and Law 2000; Law and Stokes 2005). More directly, Conover and Munch (2002) demonstrated experimentally that selective fishing can cause evolutionary change, and Olsen et al. (2004) showed that such genetic effects occurred during the decline and collapse of the northern cod fishery.

Because fisheries-induced genetic changes in stocks are not easily reversed (de Roos et al. 2006), precautionary catch quotas and other efforts to sustain old-growth age structure, including life-history reference points in stock assessments, are important tools to avoid unwanted artificial selection. Additionally, theory suggests that marine reserves can protect against strong fisheries-based selection for earlier maturation (Baskett et al. 2005).

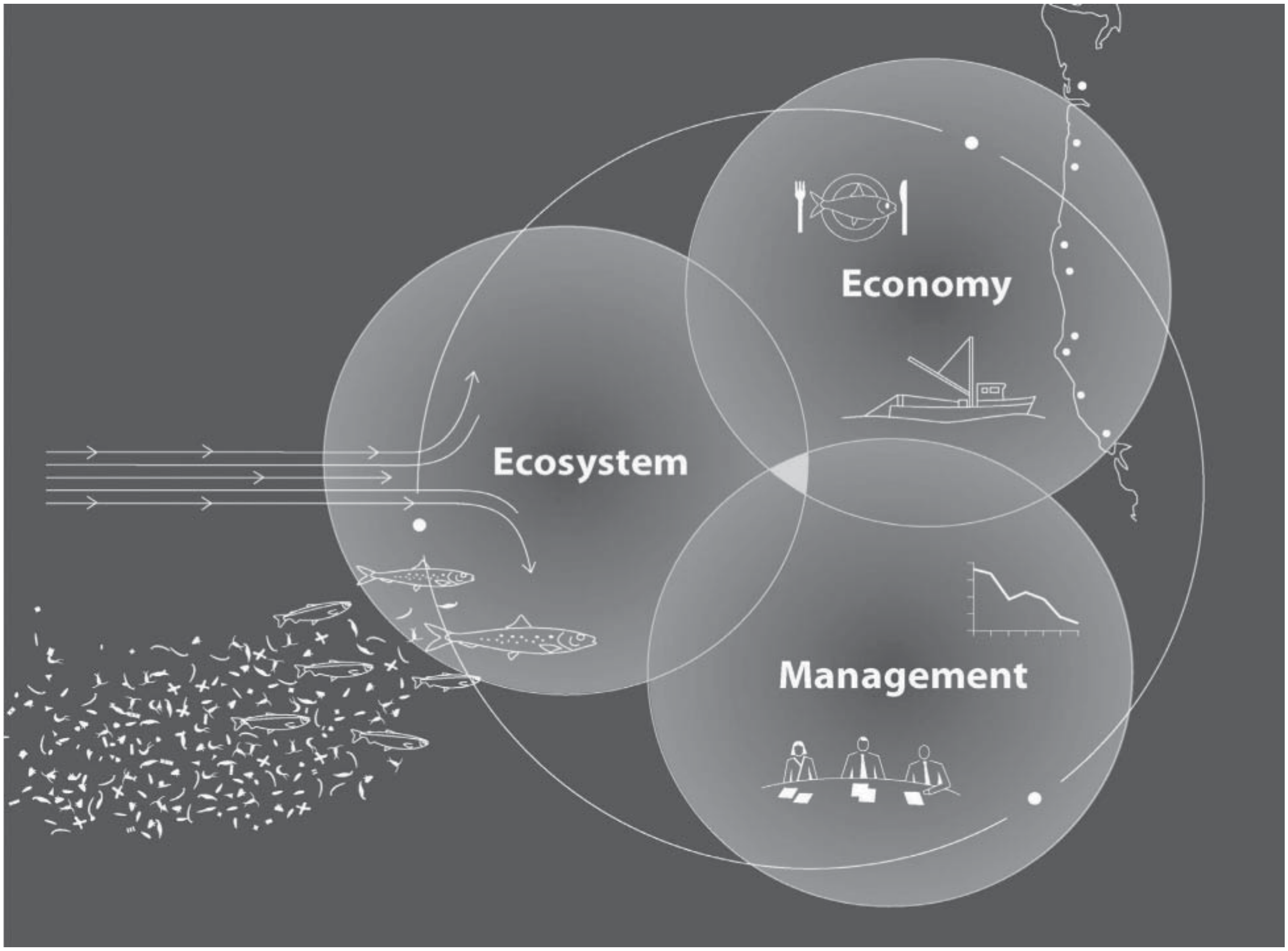
## COMMANDMENT 10:
***Implement an approach that is integrated, interdisciplinary, and inclusive.***

> *When we try to pick out anything by itself, we find it hitched to everything else in the universe.*
> —John Muir (1911:110)

The kinds of issues raised by moving to a more holistic ecosystem-based approach to fishery science simply cannot be addressed adequately by a single disciplinary perspective. These issues require an integrated view to bridge perspectives and disciplines both within and among the natural and social sciences, integrating and synthesizing knowledge from disparate disciplines into an emerging field of "integrated assessment" (Nicolson et al. 2002). Add to this synthesis the fact that fishery science is only useful to the extent that it can help facilitate resource management decisions, and the reach of ecosystem-based fishery science broadens even more. Effective implementation of ecosystem approaches to fisheries management must necessarily embrace the full range of stakeholders and all concerned citizens.

In considering integrated assessment, two important points arise. First, integrated system models are often very useful tools for interdisciplinary researchers in that they:

**Commandment 10.** Marine fisheries as integrated social-ecological systems, including ecosystem-based fisheries science (Amity Femia).




1. Help codify knowledge from different disciplines into a unified and coherent framework,
2. Encourage integrated and clear thinking about causal relationships,
3. Allow researchers, managers and stakeholders to explore plausible scenarios, and
4. Identify crucial information gaps (Nicolson et al. 2002).

Second, in concert with Holling (1993) and Holling and Meffe (1996), we propose that EBFS should focus on "second stream" approaches to science (focus on interdisciplinary, holistic relationships between nature and society) which encourage management approaches (e.g., the "golden rule" of facilitating existing processes and variability) that are proactive rather than reactive.

Finally, one of the corollaries to all of these commandments is that ecosystem-based approaches require ecosystem-based data. Not only will information gaps need to be filled by additional scientific research and monitoring, but also ecosystem-based fisheries scientists would do well to better include and integrate the vast experiential knowledge of fishermen. Although such knowledge is informal, qualitative, and provincial, the accumulated information held by the fishing community is immense and certainly an important source of supplemental data.

## THE FUTURE AWAITS

We acknowledge that these 10 "commandments" raise substantial questions regarding the details of implementation. We nonetheless argue that the ongoing paradigm shift toward ecosystem-based fisheries science must necessarily involve these action items to effectively guide fisheries management toward long-term and productive sustainability. Success will depend on creativity and ingenuity to devise specific methods to bridge the gap between general principles and full implementation. We emphasize that this paradigm shift does not comprise an abandonment of traditional fisheries biology, but rather a holistic extension of conventional approaches that grapples with the complexity of social-ecological systems in the face of incomplete knowledge.

Although the shift in worldview embodied in these commandments can occur immediately, the full implementation of ecosystem-based fisheries science will require an expanded empirical basis as well as novel approaches to modeling. This expanded knowledge base must include mechanistic ecological studies in the field, not only ocean observing systems (NRC 2003). Ultimately, we believe that ecosystem-based fisheries science must be fully implemented as soon as possible to avoid—or at least to delay—critical declines in seafood for an ever-expanding human population.

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PERSPECTIVE / PERSPECTIVE

# Ecosystem-based fisheries management: some practical suggestions

**Richard J. Marasco, Daniel Goodman, Churchill B. Grimes, Peter W. Lawson, Andre E. Punt, and Terrance J. Quinn II**

**Abstract:** Globally, there is increased scientific and public interest in the concept of ecosystem-based fisheries management (EBFM). This trend is fueled by a widespread perception that large-scale fishing operations are powerful forces altering the structure and function of marine ecosystems. It is acknowledged that management needs to better account for variations in ocean productivity, stock structure, and changing social values. Many countries are contemplating how to improve ocean fishery management. In the United States, fishery management bodies are experiencing pressure to undertake the daunting task of moving from their current single-species management plans to EBFM. Impediments include lack of a clear definition of EBFM, what it entails, or how to proceed. In this paper, characteristics of fishery management that are unique to EBFM are identified. The transition to EBFM needs to be evolutionary rather than revolutionary. A course of action is outlined that can be used to guide this transition. Modeling approaches and metrics useful for planning, implementing, and evaluating EBFM are discussed, with particular emphasis on management strategy evaluation.

**Résumé :** Il y a, à l'échelle globale, un intérêt croissant chez les scientifiques et le public en général pour le concept de gestion des pêches axée sur les écosystèmes (EBFM, ecosystem-based fisheries management). Cette tendance est alimentée par la perception que les opérations de pêche de grande envergure constituent des forces puissantes qui altèrent la structure et le fonctionnement des écosystèmes marins. On reconnaît que l'aménagement doit mieux tenir compte des variations de la productivité océanique, de la structure des stocks et des valeurs sociales changeantes. Plusieurs pays cherchent comment améliorer la gestion des pêches dans l'océan. Aux États-Unis, les organismes responsables de la gestion des pêches subissent de fortes pressions pour remplacer leurs plans actuels axés sur les espèces individuelles par l'EBFM. Une des difficultés est l'absence de définition claire de l'EBFM; il est aussi nécessaire d'en connaître les implications et de savoir comment procéder. Nous identifions ici les caractéristiques de la gestion des pêches qui se retrouvent exclusivement dans l'EBFM. La transition vers l'EBFM doit se faire par évolution plutôt que par révolution. Nous proposons un plan d'action pour guider cette transition. Nous discutons aussi des méthodologies de modélisation et des métriques utiles pour la planification, la mise en oeuvre et l'évaluation de l'EBFM avec une attention particulière portée à l'évaluation des stratégies de gestion.

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## Introduction

The desire to move towards ecosystem-based fisheries management (EBFM) is a common theme in fisheries policy and management discussions worldwide. While EBFM means different things to different people, the underlying aim is ecologically sound resource conservation that responds to the reality of ecosystem processes. There is concern about the overexploitation of fishery resources that has occurred despite the declaration of 200 mile (1 mile = 1.609 km) Exclusive Economic Zones and the establishment of governmental institutions with fisheries management authority. Fisheries extraction is the anthropogenic effect most commonly invoked as an example of the forces altering the structure and function of marine ecosystems (Pauly et al. 2002; Essington et al. 2006). Consequently, increasing attention is being focused on changing fisheries management practices and principles to protect living marine resources on an ecosystem scale.

Historically, ecology, fisheries biology, oceanography, and fisheries economics have not been well integrated in fisheries management. It is generally acknowledged that far more attention needs to be focused on a coupled understanding of many factors for more successful fisheries management. Information on physical, chemical, and biological oceanography; population biology; ecological interactions of the various species of the fish community; and the likely social and economic ramifications of management changes must be considered explicitly. This integration should be carried out with a view to better management of resources on a sustainable basis (Charles 2001).

Many countries are contemplating how to implement modern ocean fisheries management concepts. The 13th International Council for the Exploration of the Sea (ICES) Dialogue Meeting (26–27 April 2004) discussed how ICES plans to introduce an ecosystem approach (Anonymous 2004*b*). As an outgrowth of this meeting, fisheries advice from ICES in 2004 was supplemented with ecosystem considerations dealing with both the impact of fisheries on the ecosystem and the impact of ecosystems on fisheries (Anonymous 2006*b*). In 2005, ICES began discussions on reforming the structure of its expert groups that deliver science and advice, and a special meeting took place in March 2006 to develop a blueprint for the new science and advisory structures that will be required within ICES to service the demands of the ecosystem approach (Anonymous 2006*b*). The Australian Fisheries Management Authority has set out to assess the risks that fishing poses to the ecological sustainability of the marine environment for major Commonwealth fisheries (Anonymous 2006*a*). Ecological risk assessments are considered to be a key component of EBFM by the Australian Fisheries Management Authority. In 2002, Canada issued the "... Policy and Operational Framework for Integrated Management of Estuarine, Coastal and Marine Environments", which provided conceptual guidance on integrated management and planning (Anonymous 2005). This policy, which includes the concept of an ecosystem-based approach, is being tested for the Eastern Scotian Shelf (Anonymous 2004*c*). Echoing concerns contained in reports and studies regarding the sustainability of marine ecosystems and the depletion of many fish species, the US Commission on Ocean Policy (Anonymous 2004*a*) recently recommended that the United States move towards EBFM. Despite all the interest, substantial operational and definitional issues remain with EBFM and how it might be implemented.

Within the United States, Fishery Management Councils (FMCs), established in the mid-1970s under the authority of the Magnuson–Stevens Fishery Conservation and Management Act (Magnuson–Stevens Act), are the rule-making bodies charged with developing federal fishery management (consistent with other applicable policy). FMCs are faced with growing national momentum to adopt EBFM. Congressional reauthorization of the Magnuson–Stevens Act includes provisions to help redirect fishery management policies and procedures away from the traditional emphasis on single-target species and towards EBFM. Many of the FMCs' management actions can arguably be considered to reflect an overall ecosystem philosophy (Witherell 2004), and some Magnuson–Stevens Act provisions have already led to protection of essential fish habitat (EFH), reduction of bycatch, and rebuilding of overfished stocks. However, attempts at making these concepts operational based on clearly specified ecosystem guidelines and standards are still in an early stage.

There have been numerous reviews, workshops, and conferences that have addressed what EBFM is and how it should be implemented (NMFS 1999; NRC 1999; Witherell 2004). This review (initiated at the request of the Pacific States Marine Fish Commission) addresses three practical issues related to EBFM: (*i*) How should EBFM be defined for use by FMCs and other regulatory bodies? (*ii*) What characteristics are specific to an EBFM approach? (*iii*) What are the next steps that FMCs and other regulatory bodies should take to move forward from the existing management approaches to a management system that would, over time, explicitly incorporate EBFM considerations into fishery assessment and management?

While the discussion that follows draws extensively from experience in the United States, it is believed that the guidance provided will be relevant worldwide to most parties and agencies responsible for the management of fisheries.

## Defining EBFM

At present, the dominant fishery management paradigm focuses on individual species and does not incorporate ecosystem considerations in a comprehensive and transparent way. The shortcomings of this paradigm have been recognized, but not yet fully corrected (Mangel et al. 2002). Many definitions of an ecosystem-based approach to natural resource and fisheries management have recurring themes (Table 1). There is recognition of a broader constituency of uses and users of the marine environment (including fishing) and the need to accommodate and reconcile the many goals of these users so that future generations can also benefit from the full range of ecosystem goods and services. There is recognition that humans are an essential component of the ecosystem in which fishing takes place. Most importantly, these definitions recognize the interactions among physical, biological, and human components within the system. Therefore, it can be concluded that the purpose of an EBFM approach is to plan, develop, and manage fisheries in a

**Table 1.** Some existing definitions of an ecosystem-based approach to management (or fisheries management).

**The North Pacific Fishery Management Council (Witherell et al. 2000)**
An ecosystem-based approach to fisheries management is defined as the regulation of human activity towards maintaining long-term system sustainability (within the range of natural variability as we understand it) of the North Pacific covering the Gulf of Alaska, the Eastern and Western Bering Sea, and the Aleutian Islands region.

**The Food and Agricultural Organization of the United Nations (FAO Fisheries Department 2003)**
An ecosystem approach to fisheries strives to balance diverse societal objectives by taking into account the knowledge and uncertainties about biotic, abiotic, and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries.

**The Scientific Consensus Statement on Marine Ecosystem-Based Management (McLeod et al. 2005)**
Ecosystem-based management is an integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive, and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers cumulative impacts of different sectors.

**The National Research Council (NRC 1999)**
Ecosystem-based management is an approach that takes major ecosystem components and services — both structural and functional — into account in managing fisheries. It values habitat, embraces a multispecies perspective, and is committed to understanding ecosystem processes. Its goal is to achieve sustainability by appropriate fishery management.

**National Oceanic and Atmospheric Administration (Murawski and Matlock 2006)**
An ecosystem approach to management (EAM) is one that provides a comprehensive framework for living resource decision-making. In contrast to individual species or single-issue management, EAM considers a wider range of relevant ecological, environmental, and human factors bearing on societal choices regarding resource use.

manner that addresses the multiple needs and desires of society without jeopardizing the options for future generations to benefit from the full range of ecosystem goods and services.

The authors propose the following as a definition of EBFM: "Ecosystem-based fishery management recognizes the physical, biological, economic, and social interactions among the affected components of the ecosystem and attempts to manage fisheries to achieve a stipulated spectrum of societal goals, some of which may be in competition."

## Characteristics of EFBM

The identification of characteristics of EBFM is facilitated by recognizing its aim as defined above. Numerous lists of characteristics or elements have been proposed by, for example, the Ecosystem Principles Advisory Panel (NMFS 1999), the Scientific Consensus Statement on Marine Ecosystem-Based Management (McLeod et al. 2005), and the Marine Fisheries Advisory Committee's Ecosystem Approach Task Force (Busch et al. 2003). Table 2 (taken from McLeod et al. 2005) represents a good starting point for characterizing EBFM as proposed heretofore, but the authors believe that additional factors are also important. The following seven elements are specific to EBFM and are distinct from those considered routinely in single-species approaches to fisheries management. (1) Ensure that broader societal goals are taken into account. (2) Employ spatial representation. (3) Recognize the importance of climatic–oceanic conditions. (4) Emphasize food web interactions and pursue ecosystem modeling and research. (5) Incorporate improved habitat information (target and nontarget species). (6) Expand monitoring. (7) Acknowledge and respond to higher levels of uncertainty. These should, therefore, be the focus for changes to current approaches. The following sections outline each of these elements further.

### Broader goal specification and recognition

EBFM acknowledges differing uses of an ecosystem and its resources. Since fisheries goals are only a subset of societal goals, EBFM needs to embrace a broader set of impacts and goals. In the United States, this may require expanded participation and representation in the FMC process. Pertinent societal goals should include national, regional, and fishery-specific goals, but also would extend beyond conventional fisheries goals. In the United States, goals are based to a greater or lesser degree upon the Magnuson–Stevens Act, the Endangered Species Act, and the Marine Mammal Protection Act. Within an EBFM approach, broader goals reflecting society's changing values for ecosystem products and services will need to be accommodated more explicitly in management models and actions, for example as embodied in the Marine Sanctuaries Act. However, moving from high-level policy goals to operational goals remains a major challenge in situations where the goals are broad concepts such as "ecosystem integrity", "ecosystem health", and "biodiversity" (Sainsbury et al. 2000). Given a broader stakeholder base under EBFM, there also will be a need for institutions to coordinate consultations. Joint decision-making will be needed between fisheries and other non-fishery-related user groups that operate and interact in the same geographic area. Initial steps in this direction have been taken by some FMCs, as they broaden representation of civic and environmental groups on advisory committees.

### Spatial representation

Accounting more explicitly for space (spatial thinking) is a practical way of moving forward with EBFM. Although accounting for space is fundamental to an understanding of

**Table 2.** Characteristics of an ecosystem-based approach to fisheries management identified. (From McLeod et al. 2005, reproduced with permission of Communication Partnership for Science and the Sea (COMPASS).)

1. Make protecting and restoring marine ecosystems and all their services the primary focus, even above short-term economic or social goals for single services.
2. Consider cumulative effects of different activities on the diversity and interactions of species.
3. Facilitate connectivity among and within marine ecosystems by accounting for the import and export of larvae, nutrients, and food.
4. Incorporate measures that acknowledge the inherent uncertainties in ecosystem-based management and account for dynamic changes in ecosystems. In general, levels of precaution should be proportional to the amount of information available; the less that is known about a system, the more precautionary management decisions should be.
5. Create complementary and coordinated policies at global, international, national, regional, and local scales, including between coasts and watersheds (appropriate scales for management will be goal-specific).
6. Maintain historical levels of native biodiversity in ecosystems to provide resilience to both natural and human-induced changes.
7. Require evidence that an action will not cause undue harm to ecosystem functioning before allowing that action to proceed.
8. Develop multiple indicators to measure the status of ecosystem functioning, service provision, and effectiveness of management efforts.
9. Involve all stakeholders through participatory governance that accounts for both local interests and those of the wider public.

population dynamics processes (e.g., fish movements over time and space) and stock structure, single-species management has tended to focus more on temporal and age-structured considerations. Spatial thinking can help define how and where human activity (both fishing and nonfishing) affects the ecosystem, and spatial management can help to resolve conflicts among user groups through zoning for different uses, including nonextractive uses (the latter, for example, through the implementation of a system of no-take Marine Protected Areas). Without an explicit consideration of space when making management decisions, species are managed as homogeneous populations, which may impede the ability to develop prudent management measures, such as spreading catch out spatially and temporally to protect life-history characteristics and biodiversity. Spatial considerations are already being accounted for to some extent when fishery management decisions are made in the United States. For example, (*i*) restrictions were placed on the eastern Bering Sea and Gulf of Alaska walleye pollock (*Theragra chalcogramma*) fisheries to protect local availability of prey for Steller sea lions (*Eumetopeus jubatus*) around haul-out and breeding locations; (*ii*) salmon fisheries on the west coast of the United States are managed both spatially and temporally to maintain a complex stock structure and to allocate benefits between coastal communities and user groups (PFMC 2006*a*); and (*iii*) west coast groundfish management has included extensive spatial closures to reduce bycatch of overfished stocks and to protect EFH (PFMC 2006*b*).

Although a wide variety of spatial models have been developed (Quinn and Deriso 1999), there has been limited application of these models in fisheries because of the lack of necessary data on fish movement and spatial variation in biological parameters. Even when movement data are available, (e.g., Pacific halibut (*Hippoglossus stenolepis*), Quinn et al. 1990; and Gulf of Alaska sablefish (*Anoplopoma fimbria*), Heifetz and Quinn 1998), spatial models are rarely used as the basis of stock assessments, because of their greater complexity. Exceptions to this are the assessment of hoki (*Macruronus novaezelandiae*) off New Zealand (Francis 2004) and sharks off southern Australia (Punt et al. 2005). Integral to the move to EBFM is the routine examination in stock assessments of the evidence for stock and spatial structure. The lack of evidence for spatial structuring owing simply to lack of data should not be a reason to ignore the possibility of such structure. Moreover, in many cases, reasonable recommendations regarding how harvests should be distributed spatially can be made using data from surveys and catch information if there is evidence for spatial structuring, but there are insufficient data to conduct stock assessments that are spatially structured. For example, survey and catch information is already used to distribute catches spatially for many of the stocks managed by the North Pacific Fishery Management Council (NPFMC) (e.g., Gulf of Alaska walleye pollock, Pacific cod (*Gadus marcocephalus*), and sablefish; Heifetz et al. 1997).

The increasing application of geographic information systems (GIS) can be combined with traditional tagging techniques, more recent methodologies such as highly variable genetic markers (Hankin et al. 2005), and otolith microchemistry (Campana and Thorrold 2001; Miller et al. 2005; Barnett-Johnson et al. 2006) to identify population structure and estimate the extent of mixing and migration for a species. Such combined approaches will also facilitate taking better account of the spatial considerations in management.

## Climatic–oceanic conditions

There is ample evidence of the importance of regime shifts in climate and interannual variation in oceanographic conditions on the growth, reproduction, and survival of fish and other marine species (Logerwell et al. 2003; King et al. 2005; Wells et al. 2006). Some regimes favor some species over others, and this depends on life-history characteristics (e.g., longevity and maturity schedules), their position in the food chain, and other factors. For example, it is known that salmon, sardines, marine mammals, Alaska crab, walleye pollock, and other groundfish species on the west coast of the United States are sensitive to regime changes (Beamish 1995; McGinn 2002). In this respect, the difference between the North Pacific and US west coast in the last 30 years is instructive. The North Pacific (the Gulf of Alaska and the Bering Sea) experienced good environmental conditions for fish productivity beginning in about 1976. In contrast, Washington, Oregon, and California experienced poor environmental conditions over the same period (Hare et al. 1999; Peterson and Schwing 2003; King et al. 2005). As a result, fisheries in the North Pacific have been extremely productive, while those on the west coast have suffered. The poor environmental conditions off the west coast contributed to some extent to the decline of many of the groundfish species off the west coast (although fishing was almost certainly the main cause) and therefore have contributed to the need for the stringent management measures that have been implemented in this area (PFMC 2004).

Calculations of maximum sustainable yield and the rate at which overfished species are likely to rebuild are generally based on data for a period of years where it assumed that productivity was constant and will continue to be so for the projected future (Punt and Methot 2005). It therefore would be prudent for management strategies to respond to the possibility of climate changes that alter population or ecosystem productivity to detect climate-regime-related changes as soon as possible and to develop indicators to anticipate them. Necessarily, the information on how climatic–oceanic patterns might impact fish species has been obtained from retrospective analyses of oceanographic conditions and is seldom used for projection. Nevertheless, while predictive capability is still low, an important part of EBFM is to identify management strategies that are robust to ocean climate factors and their effects on species' life histories. However, it may someday be possible to develop fisheries management processes that can respond rapidly, when changes are initially detected, if ongoing efforts to expand ocean observation systems are successful. Further research to understand how ocean climate affects ecosystem processes will help in this process (Field et al. 2006) as will research into which factors provide the earliest indication of a change in the productivity regime.

## Food web interactions

Food web considerations are important in EBFM. For example, there have long been indications that harvesting species low on the food chain has disproportionately larger impacts on species at the top of the food chain. Similarly, there are indications that selective harvest of desirable top predator species can lead to simplified community structure and redirection of fisheries toward lower and lower trophic levels (Pauly et al. 2002; Essington et al. 2006).

Collection and analysis of fish stomachs to determine prey consumption by predators is crucial for the development of the information base to model and understand food web interactions. As foraging theory predicts, many species are opportunistic in their feeding habits within trophic categories (e.g., piscivores, benthic carnivores, etc.) and will switch prey if presented with appropriate-sized prey and encounter opportunity. Information on diets and how diets change over time within trophic categories is necessary to develop adequate trophic ecosystem models. Unfortunately, with the exception of databases maintained by the NMFS Northeast Fishery Science Center for the northwest Atlantic and by the Alaska Fisheries Science Center for the Gulf of Alaska and eastern Bering Sea, there are no comprehensive, long-term databases in the United States upon which reliable ecosystem models could be based.

Information on diet composition is, however, not sufficient to quantify the functional relationships between predators and prey. Changes in ocean climate can cause temporal changes in predator and prey distributions that in turn lead to changes in trophodynamics. For example, Humbolt squid (*Dosidicus gigas*) have recently extended their northern range along the west coast of the United States. Top predators such as seabirds may not be able to switch prey quickly when their preferred prey species is depleted. The impact of the loss of forage species is then evidenced by increased seabird mortality (Ainley et al. 1995; Sydeman et al. 2001).

The predictions from ecosystem models can be sensitive to assumptions regarding the functional relationships determining predation. As a result, the ability to quantify and predict how natural mortality of fish and other organisms changes over time and space is currently limited. This leads to increased uncertainty and the need for precautionary management. Some management jurisdictions (e.g., the NPFMC; Anonymous 1998*a*) have responded to this uncertainty by banning or severely restricting harvests of forage fish (Constable and de la Mare 1994; Butterworth and Punt 2003). Unlike the current generation of single-species models, most ecosystem models as presently implemented do not adequately treat uncertainty (International Whaling Commission 2004). However, even if interactions are poorly quantified, ecosystem models can be used to help shift focus to ecosystem thinking.

The implications of trophodynamic changes for fisheries management will become clearer as models are refined and species interactions are better understood. The current generation of ecosystem models should therefore be modified to more explicitly treat uncertainty. Once modified, they should be used to evaluate the benefits of additional field research and to identify the most critical data gaps. Ecosystem modeling for management support should be more focused on quantifying trade-offs among diverse goals.

It is necessary to identify the data that are cheap or easy to collect (e.g., remote sensing data collected by others), as well as to set priorities for the most important information that may be expensive to collect, but that would provide insight into important ecosystem processes. For example, there is a need to collect ecosystem data that are not associated with data already collected during fishing activities, since fishery operations are frequently limited in space and time. Further, it is important to continue research on how climatic–oceanic patterns impact target and nontarget species.

## Habitat

An increased and expanded focus on habitat considerations is needed for EBFM. The Magnuson–Stevens Act calls for the protection of EFH from fishing impacts to the extent that practical, current understanding of physical habitat for spawning, rearing, feeding, etc. of fishery species is limited. However, existing knowledge of ephemeral pelagic habitat (e.g., oceanographic features like fronts, eddies, and current patterns) is even more rudimentary (Grimes and Kingsford 1996; Grimes 2001; De Robertis et al. 2005). Similarly, habitat is an important consideration for protected species and for nonmanaged species, but habitat needs are understood for only a small fraction of these species. There also is a need to focus more attention on understanding cumulative effects from both fishing and nonfishing (e.g., point and nonpoint pollution, industrial development, and habitat alteration) activities on habitat and how productivity of both the target and nontarget species is affected.

### Expanded scope of monitoring and research

Monitoring and research for EBFM will be qualitatively new, in that it will involve new and different subject matter, but it will not replace the need for continuing current monitoring activities such as fishery-independent surveys to monitor target species. EBFM monitoring and research will be more focused on achieving a quantitative understanding of biological interactions. At an immediate and practical level, EBFM will require monitoring of total fishery removals for both target and nontarget species. There will also be a need to understand the cumulative effects of anthropogenic impacts on productivity, including those from nonfishing activities. In addition, monitoring is essential to determine the magnitude and timing of ocean climate changes and to understand how changes affect various target and nontarget species. The evaluation and improvement of marine ecosystem models should receive high priority, although the initial focus of this work should be on quantifying uncertainty and identifying critical data needs. Ecosystem modeling also needs to be more focused on quantifying trade-offs among diverse goals.

### Acknowledge and respond to high levels of uncertainty

High levels of uncertainty are a prominent feature of the present scientific understanding of ecosystem functioning, interactions among ecosystem components, and feedback loops within the ecosystem. Furthermore, the present generation of marine ecosystem models is rudimentary. Therefore, the harvest decision rules used by the FMCs to determine catch limits need to evolve in the direction of incorporating explicit probabilities (e.g., as is already the case for the decision rule used by the International Whaling Commission (1999) for the management of commercial whaling) to cope systematically with the high level of uncertainty. This will also require an evolution of policy guidelines to include a quantitative standard for what is adequately precautionary.

## Implementation of EBFM

EBFM is neither inconsistent with nor a replacement for current fisheries management. This means that EBFM should be adopted as an incremental extension of current fisheries management approaches. The challenge is to find ways to move forward given the potential costs imposed by the probable decreased harvests and the high degree of uncertainty likely to be associated with EBFM and not allowing the costs and uncertainty to be a license to maintain the status quo. Rather, the uncertainty should be taken as a mandate to improve current understanding.

The single-species assessment and management approach has a long empirical record, with well-defined models (Quinn and Deriso 1999), and research is being conducted to fill data gaps to further improve these models (Quinn 2003; Quinn and Collie 2005). Properly used, the single-species approach has been effective. Outright failures have not, for the most part, been due to the science and management approach, but rather have been due to data limitations and the lack of political will (Fogarty and Murawski 1998; Sissenwine and Mace 2001).

The single-species approach does incorporate some ecosystem considerations at least implicitly or indirectly. For example, some of the emergent properties of ecosystems can be captured, at least retrospectively, in assessment models by allowing weight-at-age to change over time and by estimating annual recruitments. However, the ecosystem is generally treated as a single, collapsed background factor in these models. Other examples where ecosystem features have been included in single-species stock assessments and management decisions are (*i*) a stock–recruitment curve with density dependence for the target species that arises from predation by another species (Quinn and Deriso 1999); (*ii*) modeled, time-varying, natural mortality that may be due to predation or disease effects (Fu and Quinn 2000; Marty et al. 2003); (*iii*) a set of years used to define biological reference points that takes into account perceived regime shifts (Quinn and Collie 2005); and (*iv*) management that accounts for stocks with low productivity by restricting harvest on all species to avoid bycatch of overfished or protected species (PFMC 2004; Breen et al. 2003). Such "weak stock" management recently restricted commercial Chinook salmon (*Oncorhychus tshawytscha*) fishing along most of the US west coast to protect the endangered Klamath River fall Chinook salmon (PFMC 2006*c*).

Perhaps the most important change required for EBFM is the change to a set of goals beyond those associated with harvest of targeted fish species. Additional scientific inputs will be needed to construct models that accommodate broader goals and alternative management strategies. As noted by Goodman et al. (2002), "… Moving from the conventional assessment view towards an ecosystem view involves a shift in the components of fundamental underlying ecological science that is relied upon. In essence, for current fishery management, population ecology is the fundamental ecological science, but for an approach that takes ecological and ecosystem considerations into account, community ecology is the fundamental ecological science. For example, when one thinks about single species, there can be "excess production" from a stock, but when one thinks about the "needs" of all the other species in an ecosystem, the notion of excess production from a single member of the community becomes far more complicated."

To be practical, the move to EBFM must be evolutionary rather than revolutionary. According to Goodman et al. (2002), the evolution involves three stages. In the first stage, assessments focus on the status of the target species and its predators and prey. Assessments are broadened in the second stage to (*i*) take into account environmental effects in a more direct fashion when determining the status of the target species and (*ii*) incorporate measures for the direct effects of fishing activities other than those on the target species (e.g., bycatch, incidental mortality, and effects on habitat). In stage three, the environment, target stock, and its predators and prey are integrated explicitly into an assessment before catch limits and other management measures are selected.

**Table 3.** Actions to promote ecosystem-based fisheries management (NMFS 1999).

1. Delineate the geographic extent of the ecosystem(s) that occur(s) within FMC (Fishery Management Council) authority, including characterization of the biological, chemical, and physical dynamics of those ecosystems, and "zone" the area for alternative uses.
2. Develop a conceptual model of the food web.
3. Describe the habitat needs of different life-history stages for all plants and animals that represent the significant food web and how they are considered in conservation and management measures.
4. Calculate total removals — including incidental mortality — and show how they relate to standing biomass, production, optimum yields, natural mortality, and trophic structure.
5. Assess how uncertainty is characterized and what kinds of buffers against uncertainty are included in conservation and management actions.
6. Develop indices of ecosystem health as targets for management.
7. Describe available long-term monitoring data and how they will be used.
8. Assess the ecological, human, and institutional elements of the ecosystem that most substantially affect fisheries and are outside FMC – Department of Commerce authority. Included should be a strategy to address those influences to achieve both Fishery Management Plan and Fishery Ecosystem Plan objectives.

The second and third stages both recognize the existence of ecosystem interactions. The second stage differs from the third in that it does not attempt to quantify the surplus production that must be reserved to satisfy ecosystem needs, nor does it attempt to modify fishing behavior to specifically mitigate adverse impacts other than those on the target species. The focus of the second stage is on the determination of the status of target and nontarget species and the evaluation of measures for the more tractable problems, such as EFH and bycatch.

In moving to EBFM, the challenge will be to diagnose the respective influences of individual environmental and ecological factors (e.g., climate and oceanographic conditions) and to develop an understanding of important processes and interactions. High levels of uncertainty will be associated with the representation of these relationships. The uncertainty results from the limitations of currently available data for estimating parameters for ecosystem models, for validating these models, and for understanding critical processes and the inherent limits of predictability of some of the underlying biological and oceanographic processes.

A critical danger is that without any track record for such models, the assumptions could be completely wrong. For this reason, changes to management strategies should also be evolutionary. During the transition to EFBM, management strategies should be similar to those used at present, (e.g., based primarily on conservative single-species management). However, selection of new management strategies that are more robust to uncertainty is possible when the results of several different ecosystem models are consistent and a management strategy evaluation shows good performance across the spectrum of possibilities. In other words, there are technical means for filtering out the most risky aspects of new, unproven models, while still being innovative.

The management system may look similar to that used at present during the transition to EBFM. However, the increased importance and use of ecosystem models will assist in the identification of approaches to consider when selecting the technical basis for providing assessments, selecting the decision rules that use the results from the assessments to define management measures, and planning investments in research and monitoring. The design and use of new models also should assure that there is at least qualitative consideration of interactions before management decisions are made.

NMFS (1999) provided a list of actions that could be taken to promote EBFM (Table 3). While the information associated with the eight items in Table 3 is relevant, it is not clear how practical they are. The concepts contained in Table 3 can be modified and extended to provide more implementation-related detail. The authors' proposed modifications are organized around application of the management strategy evaluation (MSE) approach (Goodman et al. 2002). MSE assesses the performance of a range of management strategies against a set of management goals and allows comparisons of performance among the different strategies. MSE evaluates how sensitive management strategies are to uncertainty (e.g., climate, spatial distribution, and sampling effectiveness) and may be used to evaluate a decision process that has already been adopted. Management strategies, as evaluated using the MSE approach, need to be fully specified, including, for example, specification of the data that are to be collected to support decision-making, how those data are to be analyzed to provide the input to any decision rules, and the decision rules themselves. The outcomes of an MSE are predictions of the expected performance, the trade-offs among the various (usually conflicting) management goals, and the sensitivity of the outcomes of the management strategies to various sources of uncertainty. The process of conducting an MSE to achieve EBFM involves several steps. Though the level of information and data available will change over time, the considerations identified will apply in both the short and long term.

The authors' modified list of actions is as follows: (1) Delineate and characterize the ecosystem including the ecological, human, and institutional elements of the ecosystem that most substantially affect fisheries. (2) Determine and quantify management objectives that reflect societal goals (e.g., in a single-species context, one of goals of the PFMC for groundfish is to minimize the probability that any stock is depleted to below the overfished level of 25% of the unfished biomass; however, ecosystem goals related, for example, to quantitative representations of the metrics identified by Murawski (2000) also need to be defined). (3) Develop conceptual models of (*a*) the food web and (*b*) the influence of oceanographic and climatic factors. (4) Describe the habitat needs of different life-history stages of plants and animals that represent the "significant food web" and how they are considered in conservation and management measures. (5) Expand and modify the conceptual model of the ecosystem to include life-history characteristics and spatial variation. (6) Calculate total removals, including incidental mortality, and show how they relate to standing biomass, production, optimum yields, natural mortality, and trophic structure. (7) Construct a range of alternative system models (often referred to as operating models) based on the conceptual models. Ideally, the range of system models (and the values for their parameters) should be sufficiently broad so that all plausible hypotheses regarding ecosystem processes are represented. Existing data will be used to estimate some of the parameters of these models, while for parameters that are poorly determined by existing data sensitivity will need to be explored until additional data are collected. (8) Identify a set of candidate management strategies. This will involve (*a*) assessing how uncertainty is characterized by the management agency and what kinds of buffers against uncertainty are included in conservation and management actions; (*b*) developing indices or indicators of ecosystem health as targets for management, including those based on models and how these indices can be used as the basis for decision-making. "Traffic light" approaches may be useful (Caddy 2002). Traffic light approaches assemble suites of environmental, biological, and socio-economic data into matrices of colored indicators across time. Examples for the Bering Sea and Gulf of Alaska ecosystems are given in Boldt (2006). Some have proposed using these indicators as "stop" or "go" recommendations for management. For example, if forage fish density falls below a set level, then fishing mortality would be reduced. (*c*) Describing long-term monitoring that is expected to continue and define how these data will be used for updating the parameter estimates used in the decision rules. (9) Use the management strategies to manage the simulated ecosystems represented by the system models and keep score of the achieved performance as defined by the management objectives. (10) Use the results of the simulations to (*a*) identify robust management strategies, critical data gaps, and ecological processes and (*b*) put plans in place to address the critical data gaps. (11) Select from among management strategies in light of their calculated performance and implement the selected management strategy. (12) Monitor to verify success of the management strategy and the validity of the system model on which its selection was based. (13) Revise the set of system models (hopefully the monitoring will have shown that some of the original system models were more plausible than others) and the management strategy (based on discrepancies between actual and target harvest outcomes based on the monitoring data).

Clearly the current portfolio of implemented ecosystem models does not yet span the full range of plausible system models. However, substantial progress towards implementing EBFM can take place if attempts are made to follow each of the above steps. Specifically, several ecosystem models have been developed for the US west coast, the Gulf of Alaska, and the Bering Sea – Aleutian Islands regions (Livingston and Methot 1998; Jurando-Molina et al. 2005; Guénette et al. 2006). These ecosystem models could form the basis for initial work to determine how robust current single-species management strategies are to trophic interactions and whether management strategies that include some ecosystem features are likely to outperform current approaches. Moreover, this exercise will provide an initial way to identify key sources of uncertainty and hence focus data collection strategies. In particular, if the performance of the management strategies differs markedly depending on which of several processes are actually present, experiments could be designed to attempt to distinguish among the alternative hypotheses. This approach has been used to identify causes for the marked (and undesirable) changes in the composition of the fish community on Australia's Northwest shelf and which strategy is best suited to reverse this (Sainsbury 1991; Sainsbury et al. 1997). Similarly, simulations were used to develop the current decision rule for Pacific sardine (*Sardinops sagax caerulea*) (Anonymous 1998*b*). This decision rule sets the target fishing mortality as a function of temperature because productivity of sardine has been shown to depend on temperature.

Evaluating current management strategies using existing ecosystem models as operating models may provide results of immediate use for EBFM. For example, Schweder et al. (1998) used a simple ecosystem model to assess the implications of achieving the management goals for baleen whales on likely sustainable yields for commercially important fish species. Also, Punt and Butterworth (1995) evaluated the impact of seal culls off South Africa on fish yields when the total allowable catches (TACs) for the fish species were based on the actual management strategies for these species. Similar analyses have yet to be conducted for the areas managed by the PFMC and NPFMC even though ecosystem models are available for these regions. Although the implications of simple management strategies (e.g., constant effort) have been examined using existing ecosystem models (Kitchell et al. 2002), such strategies do not adequately mimic how (single-species) management operates in reality. Only by evaluating the strategies as they are actually implemented by the FMCs will the necessary insights be achieved.

A necessary research activity to evaluate management strategies based on current ecosystem models is to expand these models so that they represent species at the same resolution as stock-assessment models (i.e., usually by age and sex). Age structure has already been added to some ecosystem models (Aydin 2004), but this is not the norm. Expanding beyond examining the implications of trophodynamics requires the construction of system models that are spatially explicit. Spatial models already exist that include trophodynamics and that could form the basis for MSE evaluations (Fulton et al. 2005). While these models are unlikely to be sufficient to evaluate all likely management strategies, the insights gained using such models at this early stage will provide decision makers with ideas regarding the way in which management strategies will have to be modified to better achieve management goals that include ecosystem considerations.

Goodman et al. (2002) suggested the need for metrics of ecosystem status in evaluating the success of EBFM. These metrics could be used as the basis for status thresholds to assess whether ecosystems are becoming unhealthy. An example of a set of ecosystem-based metrics from Murawski

(2000) is as follows: (1) The biomass of one or more important species assemblages or components falls below minimum biologically acceptable limits, such that (*a*) recruitment prospects are substantially impaired, (*b*) rebuilding times to levels allowing catches near maximum sustainable yield are extended, (*c*) prospects for recovery are jeopardized because of species interactions, and (or) (*d*) any species is threatened with local or biological extinction. (2) Diversity of communities or populations declines substantially as a result of sequential "fishing-down" of stocks, selective harvesting of ecosystem components, or other factors associated with harvest rates or species selection. (3) The pattern of species selection and harvest rates leads to greater year-to-year variation in populations or catches than would result from lower cumulative harvest rates. (4) Changes in species composition or population demographics as a result of fishing greatly decrease the resilience or resistance of the ecosystem to perturbations arising from nonbiological factors. (5) The pattern of harvest rates among interacting species results in lower cumulative net economic or social benefits than would result from a less intense overall fishing pattern. (6) Harvests of prey species or direct mortalities resulting from fishing operations impair the long-term viability of ecologically important, nonresource species (e.g., marine mammals, turtles, and seabirds).

Adopting such metrics for ecosystem status would help management bodies manage fisheries sustainably and provide thresholds for measuring their success.

## Discussion — the next steps

Many years will be required for implementation, testing, and adaptation of EBFM. However, there are ways of moving forward with most of the elements above. As a start, management bodies need to create and implement processes and institutional structures that will facilitate the identification of the full range of goals, especially those related to concerns beyond targeted species, and to make these operational.

There are also activities, such as using models to identify critical data gaps, and ecological processes that could be implemented immediately. Furthermore, ecosystem models should be developed to identify areas of high uncertainty and hence guide research and data collection. It is also important to encourage a modeling culture that rigorously quantifies the predictive power of all the models that are utilized, so that managers can make informed decisions when they consider using these models to guide actual management. It should be expected that the models on which scientific management advice is based would evolve over time from population models (single-species) to community models (taking into account food web considerations) and then to ecosystem models (taking into account environmental considerations such as habitat and climate).

Additionally, as research progresses, the fishery management approach will evolve from implicit and nonquantitative consideration of the ecosystem to a more specific and explicit quantification. It will also progress from treating ecosystem considerations outside fishery assessment and management to where these considerations are fully integrated into the process (Goodman et al. 2002).

Until the necessary research is done, it is not possible to know what the optimal management tools and their data requirements will be for EBFM. It could be that a set of single-species models combined with a collection of ecosystem indicators and prudent management strategies could suffice for many systems. For other systems, it may be necessary to develop complex ecosystem models with links among fish species, oceanography, climate, habitat, and human elements. It is also possible that the lofty goals of understanding the ecosystem and managing human uses sustainably are not fully achievable with finite resources and modeling capabilities. In that case, the goal may have to be limited to an achievable one, in which the risks of ecosystem harm are minimized through robust management strategies that set margins of safety for errors due to incomplete understanding.

Clearly the task of progressing towards EBFM will be difficult and will require substantial new investments. Management that takes ecological and ecosystem effects into account will require greatly expanded monitoring; improvement in the understanding of behavioral relationships among fishermen, the fish they catch, and the predators and prey of the harvested species; and social and economic relationships among various resource users. Additional funding and resources will be needed to get this work done. The benefits will be the explicit incorporation of societal goals in fishery management, more stable and predictable long-term yields, and the maintenance of ecosystem goods and services into the future.

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**STATUS REPORT OF THE 2007 OCEAN SALMON FISHERIES OFF WASHINGTON, OREGON, and CALIFORNIA.**

Preliminary Data Through August 31, 2007.

| Fishery and Area | Season Dates | Effort Days Fished | CHINOOK Catch | CHINOOK Quota | CHINOOK Percent | COHO[a/] Catch | COHO[a/] Quota | COHO[a/] Percent |
|---|---|---|---|---|---|---|---|---|
| **COMMERCIAL** | | | | | | | | |
| **Treaty Indian**[b/] | *5/1-6/30* | 230 | 14,944 | 21,500 | 70% | | Non-Retention | |
| | *7/1-9/15* | 355 | 7,446 | 15,500 | 48% | 35,373 | 38,000 | 93% |
| **Non-Indian North of Cape Falcon**[c/] | *5/1-6/26* | 830 | 11,158 | 10,850 | 103% | | Non-Retention | |
| | *7/1-9/16* | 682 | 4,691 | 5,092 | 92% | 17,581 | 22,400 | 78% |
| **Cape Falcon - Humbug Mt.** | *4/10-8/28* | 4,200 | 32,200 | None | NA | | Non-Retention | |
| | *9/10-10/31* | | | None | NA | | Non-Retention | |
| | *8/15-9/13* | Included Above | | None | NA | 5,700 | 10,000 | 57% |
| Florence S. Jetty - Humbug Mt. | *8/4-8/28* | | | None | NA | | Non-Retention | |
| **Humbug Mt. - OR/CA Border** | *4/10-5/31* | 14 | 23 | NA | NA | | Non-Retention | |
| | *6/1-6.30* | 137 | 744 | 1,600 | 47% | | Non-Retention | |
| | *7/11-7/31* | 95 | 1,149 | 1,600 | 72% | | Non-Retention | |
| | *8/1-8/14* | 100 | 1,600 | 1,800 | 89% | | Non-Retention | |
| | *9/6-9/30* | | | 1,000 | 0% | | Non-Retention | |
| **OR/CA Border - Humboldt S. Jetty** | *9/10-9/30* | | | 6,000 | NA | | Non-Retention | |
| **Horse Mt. - Pt. Arena** | *4/9-4/27* | 108 | 713 | 2,000 | 36% | | Non-Retention | |
| | *8/1-8/29* | 920 | 14,200 | None | NA | | Non-Retention | |
| | *9/1-9/30* | NA | NA | None | NA | | Non-Retention | |
| **Pt. Arena - Pigeon Pt.** | *5/1/-5/31* | 1,320 | 27,300 | None | NA | | Non-Retention | |
| | *7/1-8/29* | 2,780 | 39,400 | None | NA | | Non-Retention | |
| | *9/1-9/30* | NA | NA | None | NA | | Non-Retention | |
| Pt. Reyes - Pt. San Pedro | *10/1-10/12* | NA | NA | None | NA | | Non-Retention | |
| **Pigeon Pt. - Pt. Sur** | *5/1-5/31* | 1,380 | 10,560 | None | NA | | Non-Retention | |
| | *7/1-8/29* | 250 | 1,560 | None | NA | | Non-Retention | |
| | *9/1-9/30* | NA | NA | None | NA | | Non-Retention | |
| **Pt. Sur - U.S./Mexico Border** | *5/1-8/31* | 20 | 200 | None | NA | | Non-Retention | |
| | *9/1-9/30* | NA | NA | None | NA | | Non-Retention | |
| **RECREATIONAL** | | | | | | | | |
| **U.S./Canada Border - Cape Alava**[c/] | *7/3-9/15* | 12,715 | 1,420 | 1,725 | 82% | 10,184 | 12,230 | 83% |
| **Cape Alava-Queets River**[c/] | *7/3-9/15* | 2,593 | 468 | 725 | 65% | 2,649 | 2,960 | 89% |
| | *9/22-10/7* | NA | NA | 100 | NA | NA | 100 | NA |
| **Queets River - Leadbetter Pt.**[c/] | *7/1-9/16* | 23,520 | 5,038 | 9,400 | 54% | 21,134 | 28,510 | 74% |
| **Leadbetter Pt.-Cape Falcon**[c/] | *7/1-9/30* | 37,568 | 1,977 | 4,300 | 46% | 61,025 | 71,450 | 85% |
| **Cape Falcon - Humbug Mt.** | *3/15-8/31* | 54,600 | 2,200 | None | NA | | Included Below | |
| | *9/1-10/31* | | | None | NA | | Non-Retention | |
| Cape Falcon - OR/CA border | *6/23-9/16* | Included Above | | NA | NA | 41,900 | 50,000 | 84% |
| **Humbug Mt. - Horse Mt. (KMZ)** | *5/5 - 9/4* | 24,760 | 19,050 | None | NA | | Non-Retention | |
| **Horse Mt. - Pt. Arena (Ft. Bragg)** | *2/17-8/31* | 16,120 | 5,570 | None | NA | | Non-Retention | |
| | *9/1-11/11* | NA | NA | None | NA | | Non-Retention | |
| **Pt. Arena - Pigeon Pt. (San Francisco)** | *4/7-8/31* | 35,720 | 14,980 | None | NA | | Non-Retention | |
| | *9/1-11/11* | NA | NA | None | NA | | Non-Retention | |
| **Pigeon Pt. - U.S./Mexico Border** | *4/1-8/31* | 23,710 | 5,680 | None | NA | | Non-Retention | |
| | *9/1-10/7* | NA | NA | None | NA | | Non-Retention | |

| | Effort | | | Chinook Catch | | | Coho Catch[g/] | | |
|---|---|---|---|---|---|---|---|---|---|
| **TOTALS TO DATE** | **2007** | **2006** | **2005** | **2007** | **2006** | **2005** | **2007** | **2006** | **2005** |
| **TROLL** | | | | | | | | | |
| Treaty Indian | **585** | 684 | 519 | **22,390** | 25,127 | 38,303 | **35,373** | 21,130 | 19,709 |
| Washington Non-Indian | | 1,263 | 1,438 | **16,704** | 14,925 | 35,066 | **1,281** | 974 | 1,442 |
| Oregon | **4,700** | 2,595 | 7,685 | **39,100** | 24,633 | 148,893 | **17,100** | 1,192 | 2,618 |
| California | **6,778** | 5,368 | 12,624 | **93,933** | 45,087 | 256,830 | **-** | - | - |
| Total Troll | **12,063** | 9,910 | 22,266 | **172,127** | 109,772 | 479,092 | **53,754** | 23,296 | 23,769 |
| **RECREATIONAL** | | | | | | | | | |
| Washington Non-Indian | **65,382** | 59,504 | 74,549 | **8,416** | 9,623 | 29,834 | **77,819** | 33,973 | 43,322 |
| Oregon | **83,145** | 39,431 | 55,600 | **4,602** | 6,553 | 20,039 | **75,878** | 14,620 | 12,126 |
| California | **94,210** | 110,033 | 149,162 | **43,080** | 84,281 | 125,251 | **691** | 1,350 | 651 |
| Total Recreational | **242,737** | 208,968 | 279,311 | **56,098** | 100,457 | 175,124 | **154,388** | 49,943 | 56,099 |
| **PFMC Total** | **N/A** | N/A | N/A | **228,225** | 210,229 | 654,216 | **208,142** | 73,239 | 79,868 |

a/ All non-Indian coho fisheries are mark-selective except the Cape Falcon to Humbug Mt. commercial fishery.

b/ Treaty Indian effort is reported as landings.

c/ Numbers shown as chinook quotas for non-Indian troll and recreational fisheries North of Falcon are guidelines rather than quotas; only the total Chinook allowable catch is a quota.

**GENERAL MANAGEMENT ACTIONS AND INSEASON CONFERENCES**

Mar. 1 — National Marine Fisheries Service (NMFS) provides the Council with a letter outlining the 2007 management guidance for stocks listed under the Endangered Species Act (ESA).

Mar. 8 — Council recommends first inseason adjustments for:

1. Commercial fisheries between Cape Falcon and the Oregon/California border to be closed March 15 through April 9 and on April 30; landing limit of no more than 100 Chinook per vessel per calendar week in April.
2. Commercial fishery between Horse Mt. and Point Arena to be closed March 15 to April 8 and April 28-30; fishery open Monday to Friday, April 9 through the earlier of April 27 of a 2,000 Chinook quota with a landing limit of no more than 20 Chinook per vessel per day, all fish caught in the area must be landed in the area, and all fish must be offloaded within 24 hours of any closure. .

New regulations take effect May 1, 2007.

Mar. 9 — Council adopts three commercial and recreational ocean salmon fishery management options for public review.

Mar. 13 — North of Cape Falcon salmon forum meets in Lacey, Washington to initiate consideration of recommendations for treaty Indian and non-Indian salmon management options.

Mar. 26-27 — Council holds public hearings on proposed 2007 management options in Westport, Washington, Coos Bay, Oregon, and Santa Rosa, California.

Mar. 27 — North of Cape Falcon salmon forum meets in Lynnwood, Washington to further consider recommendations for treaty Indian and non-Indian salmon management options.

Apr. 5 — Council adopts final ocean salmon fishery management recommendations for approval and implementation by the U.S. Secretary of Commerce. The proposed measures comply with the salmon fishery management plan (FMP) and the current biological opinions for listed species. An emergency rule is not required for implementation.

Apr. 20 — NMFS inseason conference number two results in increasing the landing limit from 20 Chinook to 30 Chinook per vessel per day in the Horse Mt. to Point Arena commercial all salmon except coho fishery effective April 23 as only 164 fish had been caught to date on the 2,000 Chinook quota.

Apr. 27 — NMFS inseason conference number three results in no change to the Horse Mt. to Point Arena commercial all salmon except coho fishery. Only 635 Chinook were caught on the 2,000 Chinook quota, however additional sampling crews would not be available to monitor the fishery through April 30.

May 1 — Ocean salmon seasons implemented as recommended by the Council and published in the *Federal Register* on May 3 (72 FR 24539).

June 21 — NMFS inseason conference number four results in changing the U.S./Canada border to Cape Falcon, non-Indian commercial all-salmon-except-coho fishery landing limit from 60 Chinook to 50 Chinook per vessel per open period in the area north of Leadbetter Point, effective June 23 to 26. The fishery then closes through June 30, and reopens July 1 for the all species fishery.

July 19 — NMFS inseason conference number five results in no change to the Humbug Mt. to OR/CA border commercial all salmon except coho fishery, as the quota of 1,600 Chinook was projected not to be reached by July 23.

July 23 — NMFS inseason conference number six results in no change to the Humbug Mt. to OR/CA border commercial all salmon except coho fishery, as the quota of 1,600 Chinook was projected not to be reached by July 27.

July 26 — NMFS inseason conference number seven results in changing the U.S./Canada border to Cape Falcon, non-Indian commercial all-salmon fishery landing limit from 40 Chinook to 20 Chinook per vessel per open period in the area north of Leadbetter Point, effective July 28.

**GENERAL MANAGEMENT ACTIONS AND INSEASON CONFERENCES** (continued)

Aug. 13 NMFS inseason conference number eight results in closing to the Humbug Mt. to OR/CA border commercial all salmon except coho fishery, effective noon August 14, 2007, as the quota of 1,800 Chinook was projected to be reached.

Aug. 15 NMFS inseason conference number nine results in two actions:

1) changing the U.S./Canada border to Cape Falcon, non-Indian commercial all-salmon fishery to include a landing and possession limit of 140 coho per open period effective, August 18, and;
2) changing the recreational fishery north of Leadbetter Point to allow fishing seven days per week in the Westport, La Push, and Neah Bay subareas effective, August 17.

Aug. 17 NMFS inseason conference number ten results in closing the Cape Falcon to Humbug Mt. non-Indian commercial fishery to the retention of coho, effective August 20.

Aug. 22 NMFS inseason conference number 11 results in two actions:

1) transferring 5,000 marked coho from the Westport ocean subarea recreational fishery to the Columbia River ocean recreational fishery at an impact neutral rate on Lower Columbia River natural coho of 0.85 resulting in increasing the Columbia River subarea quota by 4,250 to 63,050, effective, August 25, and;
2) reopening the Cape Falcon to Humbug Mt. non-Indian commercial fishery to the retention of all legal sized coho, effective August 25 through August 28.

Aug. 28 NMFS inseason conference number 12 results in no change to the Cape Falcon. to OR/CA border recreational mark selective coho fishery as the quota of 50,000 coho was projected last through Labor Day weekend.

Aug. 30 NMFS inseason conference number 13 results in transferring 10,000 marked coho from the Westport ocean subarea recreational fishery to the Columbia River ocean recreational fishery at an impact neutral rate on Lower Columbia River natural coho of 0.84 resulting in increasing the Columbia River subarea quota by 8,400 to 71,450, and reopening the Columbia River subarea effective September 2 through the earlier of the September 30 or attainment of the subarea coho quota or north of Cape Falcon recreational Chinook quota.

**NON-INDIAN COMMERCIAL TROLL SEASONS**

Apr. 9 Horse Mountain to Point Arena, non-Indian commercial all-salmon-except-coho fishery opens Monday to Friday through April 27 with a 20 Chinook per vessel per day landing limit (changed to 30 Chinook per vessel per day effective April 23); fish caught in the area must be landed in the area, and fish must be offloaded within 24 hours of any closure.

Apr. 10 Cape Falcon to OR/CA border, non-Indian commercial all-salmon-except-coho fishery opens through April 29 with a 100 Chinook per vessel per calendar week landing and possession limit.

Apr. 27 Horse Mountain to Point Arena, non-Indian commercial all-salmon-except-coho fishery closes as scheduled.

Apr. 29 Cape Falcon to OR/CA border, non-Indian commercial all-salmon-except-coho fishery closes.

May 1 Cape Falcon to Humbug Mt., non-Indian commercial all-salmon-except-coho fishery opens through June 30.

Humbug Mt. to OR/CA border, non-Indian commercial all-salmon-except-coho fishery opens through May 31.

Pigeon Point to Point Sur, non-Indian commercial all-salmon-except-coho fishery opens through May 31; Chinook minimum size limit 27 inches total length.

Point Sur to U.S./Mexico border, non-Indian commercial all-salmon-except-coho fishery opens through September 30; Chinook minimum size limit 27 inches total length in May, June, and September and 28 inches in July and August.

**NON-INDIAN COMMERCIAL TROLL SEASONS** (continued)

| | |
|---|---|
| May 1-2 | U.S./Canada border to Cape Falcon, non-Indian commercial all-salmon-except-coho fishery opens with a 10,850 Chinook quota and a 60 Chinook per vessel landing limit north of Leadbetter Point and 40 Chinook per vessel landing limit south of Leadbetter Point for the two-day open period. The fishery reopens with the remaining quota May 5. |
| May 5-8 | U.S./Canada border to Cape Falcon, non-Indian commercial all-salmon-except-coho fishery reopens with the remainder of the 10,850 Chinook quota and a 60 Chinook per vessel landing limit north of Leadbetter Point and 40 Chinook per vessel landing limit south of Leadbetter Point for the four-day open period. The fishery reopens with the remaining quota May 12. |
| May 9 | Point Arena to Pigeon Point non-Indian commercial all-salmon-except-coho fishery opens through May 31; Chinook minimum size limit 27 inches total length. |
| May 12-Jun 12 | U.S./Canada border to Cape Falcon, non-Indian commercial all-salmon-except-coho fishery reopens Saturday to Tuesday through June 12 with the remainder of the 10,850 Chinook quota, and a 60 Chinook per vessel landing limit north of Leadbetter Point and 30 Chinook per vessel landing limit south of Leadbetter Point for each of the four-day open periods. The fishery reopens with the remaining quota June 23. |
| May 31 | Humbug Mt. to OR/CA border, non-Indian commercial all-salmon-except-coho fishery closes. Fishery reopens June 1.<br><br>Point Arena to Pigeon Point, non-Indian commercial all-salmon-except-coho fishery closes. Fishery reopens July 1.<br><br>Pigeon Point to Point Sur, non-Indian commercial all-salmon-except-coho fishery closes. Fishery reopens July 1. |
| June 1 | Humbug Mt. to OR/CA border, non-Indian commercial all-salmon-except-coho fishery opens through June 30 or a Chinook quota of 1,600 with a 30 Chinook per vessel per day and 90 Chinook per vessel per calendar week landing and possession limit. |
| June 23-26 | U.S./Canada border to Cape Falcon, non-Indian commercial all-salmon-except-coho fishery opens with the remainder of the 10,850 Chinook quota and a 50 Chinook per vessel landing limit north of Leadbetter Point and 30 Chinook per vessel landing limit south of Leadbetter Point for the final four-day open period. The fishery will not reopen June 30. |
| June 30 | Cape Falcon to Humbug Mt., non-Indian commercial all-salmon-except-coho fishery closes. The fishery reopens July 11.<br><br>Humbug Mt. to OR/CA border, non-Indian commercial all-salmon-except-coho fishery closes as scheduled. The fishery reopens July 11. |
| July 1 | U.S./Canada border to Cape Falcon, non-Indian commercial all-salmon fishery opens Saturday to Tuesday through the earlier of September 16 or quotas of 4,993 Chinook (5,400 preseason guideline minus 407 overage from the May-June fishery) and 22,400 marked coho<br>July 1-3, 7-10, 14-17, and 21-24 with a 40 Chinook per vessel landing limit north of Leadbetter Point and 20 Chinook per vessel landing limit south of Leadbetter Point for each of the open periods.<br>July 28-31, August 4-7, 11-14, with a 20 Chinook per vessel landing limit both north and south of Leadbetter Point for each of the open periods.<br>August 18-21, 25-28, September 1-4, 8-11, and 15-16 with a 20 Chinook and 140 coho per vessel landing limit both north and south of Leadbetter Point for each of the open periods.<br><br>Point Arena to Pigeon Point, non-Indian commercial all-salmon-except-coho fishery opens through August 29; Chinook minimum size limit 28 inches total length.<br><br>Pigeon Point to Point Sur, non-Indian commercial all-salmon-except-coho fishery opens through August 29; Chinook minimum size limit 28 inches total length. |

**NON-INDIAN COMMERCIAL TROLL SEASONS** (continued)

| | |
|---|---|
| July 11 | Cape Falcon to Humbug Mt., non-Indian commercial all-salmon-except-coho fishery opens through July 30. |
| | Humbug Mt. to OR/CA border, non-Indian commercial all-salmon-except-coho fishery opens through July 31 or a Chinook quota of 1,600 with a 30 Chinook per vessel per day and 90 Chinook per vessel per calendar week landing and possession limit. |
| July 30 | Cape Falcon to Humbug Mt., non-Indian commercial all-salmon-except-coho fishery closes. Fishery reopens August 4. |
| July 31 | Humbug Mt. to OR/CA border, non-Indian commercial all-salmon-except-coho fishery closes as scheduled. Fishery reopens August 1. |
| Aug. 1 | Humbug Mt. to OR/CA border, non-Indian commercial all-salmon-except-coho fishery opens through August 29 or a Chinook quota of 1,800 with a 30 Chinook per vessel per day and 90 Chinook per vessel per calendar week landing and possession limit. |
| | Horse Mt. to Point Arena non-Indian commercial all-salmon-except-coho fishery opens through August 29. |
| Aug. 4 | Cape Falcon to Humbug Mt., non-Indian commercial all-salmon-except-coho fishery opens through August 28. |
| Aug. 14 | Humbug Mt. to OR/CA border non-Indian commercial all-salmon-except-coho fishery closes at noon as the 1,800 quota is reached. Fishery reopens September 6. |
| Aug. 15 | Cape Falcon to Humbug Mt., non-Indian commercial non-mark selective coho fishery opens through earlier of August 28 or 10,000 coho quota with a 50 coho per vessel per calendar week landing and possession limit. Fishery reopens with the remaining quota on September 10. |
| Aug. 18 | U.S./Canada border to Cape Falcon, non-Indian commercial all-salmon fishery 140 marked coho per vessel per open period landing limit established. |
| Aug. 20 | Cape Falcon to Humbug Mt., non-Indian commercial non-mark selective coho fishery closes as 10,000 quota is approached. Coho retention reopens August 25. |
| Aug. 25 | Cape Falcon to Humbug Mt., non-Indian commercial non-mark selective coho fishery reopens through August 28. |
| Aug. 28 | Cape Falcon to Humbug Mt., non-Indian commercial all-salmon-except-coho fishery closes. Fishery reopens September 10. |
| | Cape Falcon to Humbug Mt., non-Indian commercial non-mark selective coho fishery closes as scheduled. Fishery is scheduled to reopen September 10 to 13 |
| Aug. 29 | Horse Mt. to Point Arena non-Indian commercial all-salmon-except-coho fishery closes. Fishery reopens September 1. |
| | Point Arena to Pigeon Point, non-Indian commercial all-salmon-except-coho fishery closes. Fishery reopens September 1. |
| | Pigeon Point to Point Sur, non-Indian commercial all-salmon-except-coho fishery closes. Fishery reopens September 1. |

**NON-INDIAN COMMERCIAL TROLL SEASONS** (continued)

| | |
|---|---|
| Sept. 1 | Horse Mt. to Point Arena non-Indian commercial all-salmon-except-coho fishery opens through the September 30. |
| | Point Arena to Pigeon Point, non-Indian commercial all-salmon-except-coho fishery opens through September 30; Chinook minimum size limit 27 inches total length. |
| | Pigeon Point to Point Sur, non-Indian commercial all-salmon-except-coho fishery opens through September 30; Chinook minimum size limit 27 inches total length. |
| Sept. 6 | Humbug Mt. to OR/CA border, non-Indian commercial all-salmon-except-coho fishery opens through September 30 or a Chinook quota of 1,000 with a 30 Chinook per vessel per day and 90 Chinook per vessel per calendar week landing and possession limit. |
| Sept. 10 | Cape Falcon to Humbug Mt., non-Indian commercial all-salmon-except-coho fishery opens through September 13 with a 150 Chinook per vessel per calendar week landing and possession limit; Bandon High Spot Control Zone closed. |
| | Cape Falcon to Humbug Mt., non-Indian commercial non-mark selective coho fishery opens through earlier of September 13 or the remainder of the 10,000 coho quota with a 50 coho per vessel per calendar week landing and possession limit. |
| | OR/CA border to Humboldt south jetty, non-Indian commercial all-salmon-except-coho fishery opens through September 30 or a Chinook quota of 6,000 with a 30 Chinook per vessel per day landing and possession limit. |
| Sept. 13 | Cape Falcon to Humbug Mt., non-Indian commercial all-salmon-except-coho fishery closes. Fishery reopens October 1. |
| | Scheduled closure of the Cape Falcon to Humbug Mt., non-Indian commercial non-mark selective coho fishery. |
| Sept. 16 | Scheduled closure of the U.S./Canada border to Cape Falcon, non-Indian commercial all-salmon fishery. |
| Sept. 30 | Scheduled closure of the Humbug Mt. to OR/CA border non-Indian commercial all-salmon-except-coho fishery. |
| | Scheduled closure of the OR/CA border to Humboldt south jetty non-Indian commercial all-salmon-except-coho fishery. |
| | Horse Mt. to Point Arena non-Indian commercial all-salmon-except-coho fishery closes. |
| | Point Arena to Pigeon Point, non-Indian commercial all-salmon-except-coho fishery closes. |
| | Pigeon Point to Point Sur, non-Indian commercial all-salmon-except-coho fishery closes. |
| | Point Sur to U.S./Mexico border, non-Indian commercial all-salmon-except-coho fishery closes. |
| Oct. 1 | Cape Falcon to Humbug Mt., non-Indian commercial all-salmon-except-coho fishery opens through October 31 with a 75 Chinook per vessel per calendar week landing and possession limit; Bandon High Spot Control Zone closed. |
| | Point Reyes to Point San Pedro, non-Indian commercial all-salmon-except-coho fishery opens Monday to Friday through October 12; all fish must be landed between Point Arena and Pigeon Point; Chinook minimum size limit 27 inches total length. |
| Oct. 12 | Point Reyes to Point San Pedro, non-Indian commercial all-salmon-except-coho fishery closes. |
| Oct. 31 | Cape Falcon to Humbug Mt., non-Indian commercial all-salmon-except-coho fishery closes. |

**TREATY INDIAN COMMERCIAL TROLL SEASONS**

| | |
|---|---|
| May 1 | All-salmon-except-coho fisheries open through the earlier of June 30 or a 21,500 Chinook quota. |
| June 30 | All-salmon-except-coho fisheries close as scheduled. |
| July 1 | All-salmon fisheries open through the earlier of September 15, a 15,500 Chinook quota (13,500 preseason quota plus 2,000 transfer from the May-June season), or a 38,000 non-mark-selective coho quota. |
| Sep. 4 | The all-salmon commercial fisheries close as the 38,000 coho quota is reached. |

**RECREATIONAL SEASONS**

| | |
|---|---|
| Feb. 17 | Horse Mt. to Point Arena, all-salmon-except-coho fishery opens through November 11. |
| Mar. 15 | Cape Falcon to Humbug Mt., all-salmon-except-coho fishery opens through October 31.<br>Cape Falcon to OR/CA border mark-selective (adipose fin clipped) coho retention allowed June 23 through September 16 (September 4 south of Humbug Mt.) with a 50,000 marked coho quota. |
| Apr. 7 | Point Arena to Pigeon Point all-salmon-except-coho fishery opens through November 11.<br><br>Pigeon Point to the U.S./Mexico border, all-salmon-except-coho fishery opens through October 7. |
| May 5 | Humbug Mt. to Horse Mt., all-salmon-except-coho fishery opens through September 4.<br>Cape Falcon to OR/CA border mark-selective (adipose fin clipped) coho retention allowed June 23 through September 4 (September 16 north of Humbug Mt.) with a 50,000 marked coho quota. |
| June 17 | Cape Falcon to OR/CA border, all-salmon mark-selective coho fishery opens through the earlier of September 16 north of Humbug Mt. or September 4 south of Humbug Mt., or a quota of 50,000 marked coho. |
| July 1 | Queets River to Leadbetter Point, all-salmon mark-selective coho fishery opens though the earlier of September 16 or a 43,510 marked coho quota (reduced to 38,510 on August 23 and to 28,510 on August 30), with a 9,400 Chinook guideline. Fishery is open Sunday to Thursday through August 17, seven days per week thereafter; daily-bag-limit of two fish, only one of which can be a Chinook. All coho must have a healed adipose fin clip. Grays Harbor Control Zone closed beginning August 1.<br><br>Leadbetter Point to Cape Falcon, all-salmon mark-selective coho fishery opens though the earlier of September 30 or a 58,800 marked coho quota, with a 4,300 Chinook guideline. Fishery is open seven days per week with a daily-bag-limit of two fish, only one of which can be a Chinook. All coho must have a healed adipose fin clip. No closure south of Tillamook Head in August. |
| July 3 | U.S./Canada border to Cape Alava, all-salmon mark-selective coho fishery opens through the earlier of September 15 or a 12,230 coho quota, with a 1,725 Chinook guideline. Fishery is open Tuesday to Saturday through August 17, seven days per week thereafter; daily-bag-limit of two fish, only one of which can be a Chinook plus one additional pink salmon beginning August 1. All coho must have a healed adipose fin clip. No chum retention in August and September.<br><br>Cape Alava to Queets River, all-salmon mark-selective coho fishery opens though the earlier of September 15 or a 2,960 coho quota, with a 725 Chinook guideline. Fishery is open Tuesday to Saturday through August 17, seven days per week thereafter; daily-bag-limit of two fish, only one of which can be a Chinook plus one additional pink salmon. All coho must have a healed adipose fin clip. |

**RECREATIONAL SEASONS** (continued)

| | |
|---|---|
| Aug. 25 | Leadbetter Point to Cape Falcon, all-salmon mark-selective coho fishery closes as the 63,050 marked coho quota is reached (58,800 preseason plus 4,250 transferred from the Westport subarea at 0.85 impact neutral rate). |
| Sept. 2 | Leadbetter Point to Cape Falcon, all-salmon mark-selective coho fishery reopens after transfer of an additional 10,000 marked coho from the Westport subarea increases the Columbia River subarea quota to 71,450 (58,800 preseason plus 4,250 transferred at an August 0.85 impact neutral rate plus 8,400 at a September impact neutral rate from the Westport subarea). |
| Sept. 4 | Humbug Mt. to Horse Mt. all-salmon-except-coho fishery closes. |
| | Humbug Mt. to OR/CA border, all-salmon mark-selective coho fishery closes as scheduled. |
| Sept. 15 | Scheduled closure of the U.S./Canada border to Cape Alava, all-salmon mark-selective coho fishery. |
| | Scheduled closure of the Cape Alava to Queets River, all-salmon mark-selective coho fishery. |
| Sept 16. | Scheduled closure of the Queets River to Leadbetter Point, all-salmon non-mark-selective fishery. |
| | Scheduled closure of the Cape Falcon to OR/CA border, all-salmon mark-selective coho fishery. The all-salmon-except-coho fishery reopens September 17 for the area north of Humbug Mt. and continues through October 31. |
| Sept. 17 | Cape Falcon to Humbug Mt., all-salmon-except-coho fishery reopens through October 31. |
| Sep. 22 | La Push area (48°00'00" N. Lat. to 47°50'00" N. Lat.), all-salmon mark-selective coho fishery opens seven days per week through the earlier of October 7, or a 100 Chinook or 100 marked coho quota. |
| Sep. 30 | Scheduled closure of the Leadbetter Point to Cape Falcon, all-salmon mark-selective coho fishery. |
| Oct. 7 | Scheduled closure of the La Push area, all-salmon mark-selective coho fishery. |
| | Pigeon Point to U.S./Mexico border, all-salmon-except-coho fishery closes. |
| Oct. 31 | Cape Falcon to Humbug Mt., all-salmon-except-coho fishery closes. |
| Nov. 11 | Horse Mt. to Point Arena, all-salmon-except-coho fishery closes. |
| | Point Arena to Pigeon Point all-salmon-except-coho fishery closes. |

a/ Unless stated otherwise, season openings or modifications of restrictions are effective at 0001 hours of the listed date. Closures are effective at 2359 hours of the listed date.