



# Marine, Estuarine, and Diadromous Fish Stocks at Risk of Extinction in North America (Exclusive of Pacific Salmonids)

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## Introduction

The problem of extinction in the sea has been recognized only recently by the scientific community (Roberts and Hawkins 1999). For the last decade, the American Fisheries Society (AFS) has pursued an initiative to identify marine fish stocks that may be at risk of extinction in North America (Musick 1998; Coleman et al. 2000; Musick et al. 2000a; Musick et al. 2000b; Parker et al. 2000). The present paper presents the first recognized AFS list of marine, estuarine, and diadromous fishes that may be at risk of extinction in North America (exclusive of Pacific salmonids). The geographic scope of this review includes the coastal waters of Mexico, the continental United States, Alaska, and Canada. The objectives in preparing this list have been to identify stocks at risk at a sufficiently early stage of decline to avoid listing as *threatened* or *endangered*, minimize the probability of under- or overestimating the risk of extinction, use the best existing knowledge of stock dynamics at low population levels, and allow experts on stocks to bring to bear all the available knowledge about life history and conservation status in order to categorize risk of extinction.

## Conservation units

The AFS recognizes the concept of Distinct Population Segments (DPS) as defined by the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) as populations that are markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors and that are significant to the species to which it belongs (Federal Register 1996). The delineation of DPSs within the legal framework of the Endangered Species Act (ESA) requires rigorous resolution that can withstand legal challenge, which is beyond the scope of the present work. Thus the DPSs recognized herein are in most instances recognizable management units that can form the basis for future more intensive reviews by NMFS or other regulatory agencies (Musick 1999a). In practice, geographic integrity and availability of population statistics may play a role in defining DPSs. Much of the data on which this review is based was derived from stock assessments prepared by regional management agencies. DPSs in this report may encompass single stocks, groups of stocks, metapopulations, subspecies, or species depending on available information about genetics, distribution, isolation, and vital life history parameters. Where multiple DPSs have been recognized within a species,

the status of those DPSs that have been assessed are noted, as well as mention of those DPSs for which no information was available or for which no assessment was made by AFS scientists.

## Categories of risk

The categories of risk recognized by AFS for various fishes and their concordance with systems used by the International Union for Conservation of Nature and Natural Resources (IUCN), Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and the Endangered Species Act of the United States (ESA) have been described in detail in Musick (1999a). AFS recognizes the following categories of risk: *endangered*, high risk of extinction in the wild in the immediate future (years); *threatened*, not *endangered* but facing risk of extinction in the near future (decades); *vulnerable (special concern)*, not *endangered* or *threatened* severely but at possible risk of falling into one of these categories in the near future; *conservation dependent*, reduced but stabilized or recovering under a continuing conservation plan; *not at risk*, not at apparent risk of extinction. This category may include DPSs that have been severely overfished as well as healthy DPSs. The AFS categories deal with extinction risk and not growth or recruitment overfishing except where recruitment overfishing may threaten the DPS with extinction.

## Criteria to define risk

The development of the AFS criteria to assess extinction risk was described in detail in Musick (1999a). These criteria include:

- (1) **Rarity:** Some species are known only from a small

**Table 1.** Suggested values for productivity index parameters: intrinsic rate of increase ( $r$ ), von Bertalanffy ( $k$ ), fecundity (Fec.), age at maturity ( $T_{mat}$ ), and maximum age ( $T_{max}$ ). DPSs may be classified according to their production as high, medium, low, and very low. The parameters are suggested only as guidelines and may not be consistent within all DPSs because of the great diversity of life history strategies among fishes (after Musick 1999a).

Productivity Parameter	High	Medium	Low	Very low
$r$ (yr. $^{-1}$ )	> .50	.16–.50	.05–.15	< .05
von Bertalanffy, $k$	> .30	.16–.30	.05–.15	< .05
Fec. (yr. $^{-1}$ )	> $10^4$	$10^2$ – $10^3$	$10^1$ < $10^2$	< $10^1$
$T_{mat}$	< 1 yr.	2–4 yr.	5–10 yr.	> 10 yr.
$T_{max}$	1–3 yr.	4–10 yr.	11–30 yr.	> 30 yr.



number of specimens, or they occur in collections infrequently and in small numbers. These species may be inherently rare because of ecological or evolutionary factors, or they may be merely cryptic or elusive. Until such questions are answered by qualified experts, rare species should be classified at least as *vulnerable*.

(2) **Small range and endemics:** Species that are endemic or restricted in range to some relatively small, contiguous geographic entity (i.e., island, archipelago, river system, etc.) in which the habitat is or may be under threat of degradation or destruction should be classified as *vulnerable*. Where significant habitat loss has occurred or is occurring, such species should be classified as *threatened* or *endangered*. Significant habitat loss should be evaluated on a case by case basis in the context of the biology of the DPS under consideration and on both the amount of critical habitat available and the vulnerability of that habitat.

(3) **Specialized habitat requirements:** Some species may be relatively widespread but occupy very specific habitats within their range and/or during some specific life history stage. Therefore, their area of occupancy may represent only a small part of that range. When habitats are particularly vulnerable (such as coral reefs and seagrass beds) and subject to degradation, destruction, or fragmentation, habitat loss could be the critical factor leading to population reduction or extirpation. Habitat loss should be examined as a risk factor in the context of the biology of the DPS under consideration. In some instances a 10% loss may lead to listing; in others a  $\geq 50\%$  loss may pose no extirpation threat.

(4) **Population decline:** Decline as a risk factor depends heavily on stock resilience or intrinsic rate of increase, therefore AFS has adopted a two-tiered system that first assigns DPSs into one of four categories of resilience or productivity. DPSs may be classified using any or all available information on the following: the intrinsic rate of increase,  $r$  (expressed as an instantaneous rate or annual percentage); the von Bertalanffy growth coefficient,  $k$ ; fecundity (Fec); age at maturity ( $T_{mat}$ ); and maximum age ( $T_{max}$ ) (Table 1). The values used in Table 1 are based on reviews of vital parameters in Musick (1999a, b). The intrinsic rate of increase is the real key to resilience since it incorporates all of the other components in Table 1 (Musick 1999a). When information on  $r$  is available, it should take precedence in assigning a DPS to a productivity category. The intrinsic rate of increase may be approximated by the realized rate of increase when empirical observations of population recovery from low abundance are available. Age at maturity is the next most important index after intrinsic increase rate, and it is often correlated with the growth coefficient  $k$  and with maximum age (Musick 1999a). Fecundity may be particularly valuable in flagging those DPSs at the lower end of the scale, but may be misleading for DPSs at the high end of the scale. Many fishes exhibit a direct correlation between age or size and fecundity. For the purposes of the AFS categorization, we suggest using the fecundity at first maturity. In the absence of an estimate of  $r$ , the DPS should be classified according to the lowest productivity category for which data are available in the table. Consequently, a fish with

**Table 2.** Provisional decline thresholds for four categories of DPSs based on population resilience. If a decline reaches a threshold, the DPS would be listed as vulnerable and subjected to close scrutiny for further listing (after Musick 1999a).

Productivity	Threshold Decline (over the longer of 10 yrs. or 3 generations)
High	.99
Medium	.95
Low	.85
Very Low	.70

high fecundity ( $\geq 10^4$ ), but late maturity (5–10 yr.), and long life span ( $\geq 30$  yr.), would be classified under the very low productivity category.

Once a DPS's resilience has been estimated, its estimated decline can be compared to the decline thresholds suggested in Table 2. These thresholds are provisional and are based on observed population declines noted in Musick 1999a, and the need to be precautionary. If the decline equals or exceeds the threshold for the appropriate productivity category, the DPS would be automatically listed as *vulnerable* and flagged for further study by expert scientists, who may decide to upgrade the level of threat to *threatened* or *endangered*, or downgrade the status, if appropriate. These expert evaluations should incorporate all available, pertinent information on the biology of the DPS in question. Reasons for downgrading might be that the stock has come under recent management and has stabilized so it would be *conservation dependent*, or that even after a decline down to 1/1000, the DPS still persists in significant numbers in the environment. Some marine fish stocks are so large that this scenario may not be unusual. Declines should be measured in terms of mature individuals, which might be expressed as numbers or biomass. In DPSs where one sex strongly limits the reproductive capacity of the population, then only the decline in the limiting sex should be considered.



With an estimated 92.5% decline in population, the lingcod (*Ophiodon elongatus*) is classified as *vulnerable*.

Dan Corshall/AFS Fish Slide catalog

## ENDANGERED SPECIES

### Documentation

Documentation of this list of DPSs at risk has been drawn from the published literature, unpublished management agency reports and stock assessments, and queries of regional scientists and species-group specialists. Departure from standard AFS publication protocol of citing only peer-reviewed, published literature was dictated by the paucity of published information on many DPSs that had a high probability of being at risk; (i.e., the first peer-reviewed publication on the population status of some of these DPSs might constitute an epitaph.) We have attempted to strike a scientific balance between not listing species under decline but not at risk, and the precautionary approach required when dealing with potentially endangered species. Certainly this list is not perfect and is subject to future revision. It represents the first intensive effort by AFS to identify marine fishes at risk of extinction in North American waters. Our review has resulted in the removal of several species that had previously appeared in earlier draft lists (Huntsman 1994; Musick 1998). Those species were removed because reasonable evidence suggested they were not at risk of extinction.

### Format

The list is presented systematically following the arrangement in Robins et al. (1991) and Nelson et al. (in press). Species or subspecies assessed are listed by family. Within each specific account the following format is followed: scientific name, common name, range, habitat (marine, estuarine, anadromous, catadromous, amphidromous, etc.), risk factors, official status, and AFS status by DPS.

#### Rhincodontidae

##### Rhincodon typus **whale shark**

*Range:* Circumtropical: NY (rare) to Brazil (Robins et al. 1986); occasional s. CA, Gulf of Calif. to Galapagos (Eschmeyer et al. 1983).

*Habitat:* Pelagic coastal and oceanic.

*Risk Factors:* Largest living fish, with probable low to very low

productivity, known mostly from small local populations or scattered individuals, rare in Atlantic and Gulf of Mexico. *Official Status:* Protected under Fisheries Management Plan (FMP) in U.S. Atlantic.

*Status by DPS:* *Conservation dependent*, U.S. Atlantic and Gulf of Mexico; *not at risk*, Gulf of Calif.

#### Odontaspidae

##### Odontaspis taurus **sand tiger shark**

*Range:* Atlantic, Indian, and w. Pacific Oceans in warm temperate areas, Cape Cod to Argentina (Compagno 1984; Robins et al. 1986).

*Habitat:* Shallow coastal.

*Risk Factors:* Very low productivity (Fec., r) (Goldman 1998).

*Official Status:* Candidate List, U.S.; protected by FMP in U.S.

*Status by DPS:* *Vulnerable*, w. Atlantic populations declined by ~90% from overfishing from early 1980s to mid 1990s; populations may be stabilized under FMP but recovery not yet apparent (Musick 1999a; Musick et al. 1993).

#### Cetorhinidae

##### Cetorhinus maximus **basking shark**

*Range:* Circumglobal in cold temperate waters, Newfoundland to n. FL (winters), Aleutian Isl. to Gulf of Calif.

(Compagno 1984), Gulf of Calif. population poorly documented (1950s) and likely was isolated in northernmost part (L. Findley, pers. observ.).

*Habitat:* Coastal pelagic.

*Risk Factors:* Low to very low productivity ( $k$ ,  $T_{max}$ ,  $T_{mat}$ ) (Pauly 1978a). Historic fisheries off n. Europe and CA led to stock collapses (S. L. Fowler in press).

*Official Status:* Protected by FMP in U.S. Atlantic.

*Status by DPS:* *Vulnerable*, e. Pacific, no recent records from Gulf of Calif. indicates that it is now likely extirpated (L. Findley, pers. observ.); *conservation dependent*, w. Atlantic.

#### Lamnidae

##### Carcharodon carcharias **white shark**

*Range:* Circumglobal in temperate coastal waters; occasionally tropical, NF, to n. South America; Gulf of Alaska to Gulf of Calif. (Eschmeyer et al. 1983; Robins et al. 1986).

*Habitat:* Coastal, occasionally oceanic, most common near pinniped colonies.

*Risk Factors:* Largest predatory shark, low to very low productivity ( $k$ ,  $T_{max}$ ) (Cailliet et al. 1985; Ferguson 1996; Francis 1996). Apex predator occurring in small, seasonally local populations.

*Official Status:* Protected by FMP in U.S. Atlantic; protected by state of CA.

*Status by DPS:* *Conservation dependent*, w. Atlantic and e.

Pacific, rare in Gulf of Calif. where it is fished by small-scale long-liners (L. Findley, pers. observ.).

#### Carcharhinidae

##### Carcharhinus obscurus **dusky shark**

*Range:* Circumglobal in warm temperate and tropical seas; Cape Cod to Brazil (Robins et al. 1986), s. CA to Gulf of Calif. (Eschmeyer et al. 1983).



The basking shark (*Cetorhinus maximus*) is classified as *vulnerable* in the Pacific and *conservation dependent* in the Atlantic.

*Habitat:* Coastal, occasional oceanic.

*Risk Factors:* Very low productivity ( $k$ ,  $T_{max}$ ,  $T_{mat}$ ,  $r$ ) (Cortés 1998).

*Official Status:* Candidate List, U.S.; protected, in part, in Atlantic by U.S. FMP.

*Status by DPS:* *Vulnerable*, w. Atlantic and e. Pacific, 90% decline in Atlantic during 1980s (Musick et al. 1993), recovery not apparent (Musick 1999a), still high mortality in Mexican fisheries in both Atlantic and Gulf of Calif., bycatch mortality high in U.S. long-line fisheries.

***Carcharhinus signatus*** **night shark**

*Range:* DE to s. Brazil, also w. Africa, mostly tropical (Robins et al. 1986).

*Habitat:* Pelagic oceanic and shelf edge, Gulf stream.

*Risk Factors:* Probable low to very low productivity ( $k$ ,  $T_{mat}$ ).

*Official Status:* Candidate List, U.S.; protected in part by U.S. FMP in Atlantic.

*Status by DPS:* *Vulnerable*, w. Atlantic 90% decline (Castro et al. 1999), bycatch mortality high in long-line fisheries.

**Pristidae**

***Pristis pectinata*** **smalltooth sawfish**

*Range:* W. Atlantic: NC, Bermuda, n. Gulf of Mexico to Brazil (Robins et al. 1986); e. Atlantic, Mediterranean Sea; Indo-West Pacific (Compagno 1997).

*Habitat:* Marine, estuarine < 25 m (Adams and Wilson 1995).

*Risk Factors:* Low productivity ( $r$ ,  $k$ , fec.,  $T_{mat}$ ) (Simpfendorfer 2000), entrapment in fishing gear (commercial and recreational); products of commercial value—rostral “saws” sold as curios, Asian medicines from “saws,” and leather from hides (Federal Register 1997).

*Official Status:* Candidate List, U.S.

*Status by DPS:* *Endangered*, U.S., Mexico, extirpated from Indian R. (FL) system where once abundant (Snelson and Williams 1981). Once abundant now rare in s.e. U.S. and Mexico (L. Castillo, Federal Secretary of Environment, Natural Resources and Fisheries, Mexico City, pers. comm.). Range in U.S. has declined by 90% in last 40 years (Adams and Wilson 1995). Last remaining population in U.S. in s. FL (T. Schmidt, National Park Service data). Limited quantitative data for stock assessment (Adams and Wilson 1995).

***Pristis perotteti*** **largetooth sawfish**

*Range:* N. TX and FL to Brazil, also in e. Pacific, e. Atlantic, and possibly Mediterranean (Baughman 1943, 1952; Cook et al. in press).

*Habitat:* Coastal marine (< 10 m), estuarine and freshwater (Cook et al. in press).

*Risk Factors:* Low productivity ( $r$ ,  $k$ , fec.,  $T_{mat}$ ) (Simpfendorfer 2000).

*Official Status:* Candidate List, U.S.

*Status by DPS:* *Endangered*, possibly extirpated in U.S. waters, no recent records. Rare in Mexico (L. Castillo, Federal Secretary of the Environment, Natural Resources and Fisheries, Mexico City, pers. comm.), probably extirpated in Gulf of Calif. (L. Findley, pers. observ.) Some freshwater populations extirpated in Central America (Thorson 1982).

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The yelloweye rockfish (*Sebastes ruberrimus*) has very low productivity and has virtually disappeared from recreational catches in Puget Sound.

**Rajidae**

***Amblyraja radiata*** **thorny skate**

*Range:* W. Greenland and Hudson Bay to SC (in deep water) (Robins et al. 1986).

*Habitat:* Benthic, coastal to upper slope.

*Risk Factors:* Probable low to very low productivity, taken as unrecorded bycatch in trawl fishery for groundfish.

*Official Status:* None, NMFS review found U.S. stocks to be overfished (NFSC 2000a).

*Status by DPS:* *Vulnerable*, U.S., 85–90% decline since 1970 (NFSC 2000a); *not assessed*, Canadian stocks.

***Dipturus binoculata*** **big skate**

*Range:* Bering Sea and s.e. Alaska to cen. Baja Calif., rare south of Point Conception, CA (Eschmeyer et al. 1983).

*Habitat:* Benthic, coastal.

*Risk Factors:* Low to very low productivity ( $k$ ,  $T_{max}$ ,  $T_{mat}$ ) (Zeiner and Wolf 1993), taken as unrecorded bycatch in ground fisheries, and directed skate fisheries (Martin and Zorzi 1993).

*Official Status:* None.

*Status by DPS:* *Vulnerable*, although little data exist on recent population trends, its low productivity and stock collapses and local extirpations in closely related species in the w. and e. Atlantic (Casey and Meyers 1998) suggest it is probably at risk. A population assessment is sorely needed.

***Dipturus laevis*** **barndoor skate**

*Range:* Grand Banks to NC (Robins et al. 1986).

*Habitat:* Benthic, shallow coastal to upper continental slope

*Risk Factors:* Low to very low productivity, taken as unrecorded bycatch in trawl fishery for groundfish (Casey and Myers 1998; NFSC 2000b).

*Official Status:* Candidate List, U.S., NMFS review found U.S. stocks to be overfished but not at risk of extinction.

*Status by DPS:* *Vulnerable*, northernmost Canadian stocks

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may be extirpated (Casey and Meyers 1998), 95% decline in other stocks in late 1960s, slight recent increase in abundance of stocks on Georges Bank and w. Scotian shelf, also persists in deep water of Scotian slope (NFSC 2000b), recent increase seems to have been mitigated by regulations restricting the ground fishery but not targeted at this species.

### Acipenseridae

#### Acipenser brevirostrum **shortnose sturgeon**

**Range:** St. Johns R., NB, to St. Johns R., FL. (NMFS 1998).

**Habitat:** Semi-anadromous, some freshwater.

**Risk Factors:** Very low productivity ( $T_{max}$ ) (Dadswell et al. 1984), 98% decline throughout its range (Smith and Clugston 1997), freshwater spawning and nursery areas destroyed or degraded.

**Official Status:** *Endangered*, U.S.; *special concern*, Canada.

**Status by DPS** (data from NMFS 1998): *Endangered* (rare), Penobscot R., Merrimack R., Chesapeake Bay System, Cape Fear R., Santee R., Cooper R., Ashepoo R., Combahee R., Edisto R., Ogeechee R., Satilla R., St. Marys R., St. Johns R.; *threatened*, Kennebec R. system, Delaware R.; *conservation dependent*, St. John R., Hudson R., Savannah R., Altamaha R.

Dan Gotshall/AFS Fish Slide catalog



The rare green sturgeon (*Acipenser medirostris*) is *endangered* in California and Oregon.

#### Acipenser medirostris **green sturgeon**

**Range:** Aleutian Isl., AK, to Ensenada (n. Baja Calif.), Mexico (Houston 1988).

**Habitat:** Anadromous.

**Risk Factors:** Rare, probable very low productivity, 88% decline in most of range, specialized habitat requirements (Houston 1988).

**Official Status:** None, U.S.; *special concern*, Canada.

**Status by DPS:** *Endangered*, U.S. (CA), spawning apparently restricted to Klamath and Sacramento rivers and possibly the Rogue R. (OR). Number of mature females in each DPS probably in low hundreds (S. G. Wright, pers. observ.). Although demographic parameters for this rare species are unknown, it should be listed because of extreme vulnerability of sturgeons in general (Birstein 1993). *Vulnerable*, Canada. Data needed for more precise determination of status.

#### Acipenser oxyrinchus desotoi **gulf sturgeon**

**Range:** Mississippi R., LA, to Florida Bay, FL. (USFWS and GSMFC 1995).

**Habitat:** Anadromous.

**Risk Factors:** Very low productivity ( $k$ ,  $T_{mat}$ ,  $T_{max}$ ) (USFWS and GSMFC 1995), 98% decline throughout its range (Smith and Clugston 1997), specialized habitat requirements.

**Official Status:** *Threatened*, U.S.

**Status by DPS:** Not established, possible populations as recognized by the Gulf Sturgeon Management/Recovery Plan (USFWS and GSMFC 1995): *endangered*, Mississippi R., Lake Pontchartrain System, Mississippi Sound, Biloxi Bay System, Pascagoula R., Mobile R., Pensacola Bay System, Choctawhatchee Bay System, Ochlockonee R., Tampa Bay System, Charlotte Harbor System; *threatened*, Mermantau R., Apalachicola R., Chattahoochee R., and Flint R., Suwannee R.

#### Acipenser oxyrinchus oxyrinchus **Atlantic sturgeon**

**Range:** Hamilton Inlet, Labrador, to the St. Johns R., FL.

(Colligan et al. 1998).

**Habitat:** Anadromous.

**Risk Factors:** Very low productivity ( $k$ ,  $T_{mat}$ ,  $T_{max}$ ) (Colligan et al. 1998; Stevenson and Secor 1999), 98% decline throughout its range (Smith and Clugston 1997), specialized habitat requirements (Colligan et al. 1998).

**Official Status:** Candidate List, U.S.; protected by FMP. (ASFMC 1996); *special concern*, Canada.

**Status by DPS:** Colligan et al. (1998) concluded that there is not enough evidence to divide the Atlantic sturgeon into DPSs. In this report, river systems are used as a proxy for DPSs: *Extirpated*, St. Marys and St. Johns rivers, FL; *endangered*, n. Canadian Rivers, St. Lawrence R., Penobscot R., Piscataqua/Great Bay estuary, Merrimack R., Taunton R., Connecticut R., Thames R., Housatonic R., Chesapeake Bay System, Winyah Bay rivers, Santee R., Cooper R., Port Royal Sound rivers, Ogeechee R., Satilla R.; *threatened*, St. Johns R., (Kennebec R., Androscoggin R. and Sheepscot R.), NC rivers, Ashepoo R., Combahee R., Edisto R., Savannah R.; *conservation dependent*: Hudson, Delaware, and Altamaha rivers.

#### Acipenser transmontanus **white sturgeon**

**Range:** Alaska Bay, AK, to Ensenada (n. Baja Calif.), Mexico (PSMFC 1992).

**Habitat:** Semi-anadromous; some freshwater (land-locked by dams).

**Risk Factors:** Very low productivity ( $k$ ,  $T_{mat}$ ,  $T_{max}$ ) (Brennan and Cailliet 1989), 88% decline in most of its range (Cech 1992), specialized habitat requirements (Cech 1992).

**Official Status:** *Endangered*, Kootenai R. system, U.S.; *special concern*, Canada.

**Status by DPS:** [DPSs here are management units and "potential" management units from PSMFC (1992)]: *Endangered*, upper Columbia (upstream of Chief Joseph Dam), upper Snake R. (upstream of Lower Granite Dam), Fraser R.; *threatened*, mid Columbia and Snake Rivers (to Chief Joseph Dam on Columbia R. and to Lower Granite Dam on Snake R.), upper Snake R. (upstream of Lower Granite Dam). PSMFC's "potential" management units:

Klamath/Trinity R. basin; Rogue R.; Coos Bay system; *conservation dependent*, Sacramento R. and San Joaquin R., lower Columbia R. (to Bonneville Dam); *not assessed*, CA coast, OR coast, Umpqua R., Yaquina R., Tillamook Bay, WA coast-Puget Sound, Canadian and AK coastal waters.

**Clupeidae**

***Alosa alabamae***

**Alabama shad**

*Range:* Apalachicola R., FL; Escambia R. and Perdido R., AL (Boschung 1992); spawns in Choctawhatchee R. and Conecuh R., AL (Mettee et al. 1989); Leaf R., MS (Poss 1998).

*Habitat:* Anadromous.

*Risk Factors:* Migration barriers in Mississippi R. drainages, habitat degradation, decline in water quality (Poss 1999).

*Official Status:* Candidate List, U.S.

*Status by DPS:* *Vulnerable*, rare in MS state drainages (Burgess 1980), more information needed to determine range in Gulf of Mexico drainages, life history, and population dynamics (Poss 1998).

***Clupea pallasii***

**Pacific herring**

*Range:* Korea and Japan to arctic AK and to n. Baja Calif. (Eschmeyer et al. 1983).

*Habitat:* Marine.

*Risk Factors:* Medium productivity ( $T_{mat}$ ) evidence for metapopulation structure in *Clupea* (McQuinn 1997) with population or stock aggregations spawning demersal eggs at specific sites. These aggregations particularly vulnerable to overharvesting.

*Official Status:* Candidate List, U.S. (Puget Sound only).

*Status by DPS:* *Vulnerable*, Puget Sound, 4 of 8 stocks may have declined by 90–95% from overharvesting while annual natural mortality has increased from 20% to 80% because of increased pinniped predation mitigated by increase in local pinniped populations (West 1997); other DPSs: *not assessed*.

**Osmeridae**

***Hypomesus transpacificus***

**delta smelt**

*Range:* Sacramento-San Joaquin river system, cen. CA (Eschmeyer et al. 1983).

*Habitat:* Estuarine to freshwater, semi-anadromous.

*Risk Factors:* Endemic to rivers where agriculture and urban water diversions have been extreme thus severely degrading its habitat. (Moyle and Sweetnam 1994).

*Official Status:* *Threatened*, U.S., CA (CA Department of Fish and Game 2000).

*Status by DPS:* *Threatened*, large decline recorded in late 1970s with no recovery since (Moyle and Sweetnam 1994).

***Spirinchus thaleichthys***

**longfin smelt**

*Range:* Prince William Sound, AK, to Monterey Bay, cen. CA (Eschmeyer et al. 1983).

*Habitat:* Anadromous.

*Risk Factors:* Habitat destruction and alteration of spawning and nursery areas, dams, logging, agricultural water diversions.

*Official Status:* None, U.S.; *special concern*, CA (website analysis suggests severely endangered) (CA Department



Brent Cooke/AFS Fish Slide catalog

The tiger rockfish (*Sebastes nigrocinctus*) is in long-term decline in Puget Sound.

of Fish and Game 2000).

*Status by DPS:* *Threatened*, CA, once abundant in n. CA, now rare (Moyle et al. 1995); *vulnerable*, other DPSs in U.S.; *not at risk*, AK (J. Blackburn, AK Department of Fish and Game, Kodiak, pers. comm.), *not assessed*, Canada.

***Thaleichthys pacificus***

**eulachon**

*Range:* Pribilof Isl. (Bering Sea) to Monterey Bay, CA. (Eschmeyer et al 1983).

*Habitat:* Anadromous.

*Risk Factors:* Medium productivity ( $T_{mat}$ ), vulnerable habitat in freshwater spawning and nursery grounds, dams, clearcut logging and siltation, agricultural and dredging impacts, also overharvesting of localized spawning runs and bycatch in other fisheries.

*Official Status:* *Special Concern*, CA; None, Canada, U.S.

*Status by DPS:* *Threatened*, Columbia R., commercial landings have declined from average of 2.1 million lbs. annually from 1938–1989 to 5,000 lbs. in 1999, a decline > 0.99 (Wright 1999a). NMFS review questions integrity of Columbia R. population as a DPS (Rosenburg 1999), but magnitude of decline contradicts this; Wright (2000) presents compelling evidence that ESA listing of this DPS should be reconsidered. Other DPSs from BC to n. CA may have declines similar to that observed in Columbia R. (Barker 1998); other confirmed spawning populations in the Sacramento, Klamath and Rogue Rivers; *vulnerable*, Canada (Hay et al. 1997) *not at risk*, AK (J. Blackburn, AK Department of Fish and Game, Kodiak, pers. comm.).

**Salmonidae**

Only the Atlantic salmon is assessed here. Pacific salmonids have been assessed by AFS previously (Nehlsen et al. 1991).

***Salmo salar***

**Atlantic salmon**

*Range:* Ungava Bay, Labrador, to Connecticut R., U.S.; also Iceland, British Isles, and n. Europe (Coad 1992),

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historically native to nearly every major coastal river north of the Hudson R., NY (Kendall 1935).

*Habitat:* Anadromous.

*Risk Factors:* Overfishing and habitat destruction of spawning and nursery areas. Habitat degraded by water pollution, dams, logging, peat mining, and acid rain (USFWS 1999).

*Official Status:* Candidate List, U.S.; proposed *endangered* status, U.S. (Federal Register 1999).

*Status by DPS:* *Endangered*, Gulf of Maine, all U.S. populations extirpated except for remnants in eight rivers in ME (USFWS 1999). In addition, escapement of salmon produced under aquaculture threatens native stocks through competition and genetic swamping of native genotypes (USFWS 1999).

*DPS in Canada:* *Endangered*, 33 interior Bay of Fundy rivers from St. Johns R., NB, to Annapolis R., NS (population declined from 40,000 in mid-1980s to a few hundred in 1999), NS e. and s. rivers (populations extirpated in 14 rivers, acid rain and water quality problems); *threatened*, St. Croix R. to St. Johns R., NB; *vulnerable*, Miramichi R.; *not at risk*, Restigouche R., NS, Northumberland Strait and Cape Breton Isl., most rivers in NF and PQ; *not assessed*, Labrador (ASF 2000; DFO 2000).

### Gadidae

#### *Gadus macrocephalus*

#### Pacific cod

*Range:* Japan to Bering Sea and to Santa Monica (s. CA), rare s. of n. CA (Eschmeyer et al. 1983).

*Habitat:* Marine.

*Risk Factors:* Low productivity ( $T_{max}$ ) (Love 1991). May form localized spawning aggregations, vulnerable to overfishing (Wright 1999b).

*Official Status:* Candidate List, U.S. (Puget Sound only).

*Status by DPS:* *Vulnerable*, Puget Sound, populations have declined by 80–90% since 1970s (Palsson et al. 1997). No indication of recovery despite fishery regulations (West 1997; Wright 1999b). Recovery may be hampered by warming water temperatures (Palsson 1990); other DPSs, *not at risk* (Thompson and Dorn 1999; Thompson et al. 1999).

#### *Gadus morhua*

#### Atlantic cod

*Range:* S. Greenland and s.e. Baffin Isl. to Cape Hatteras (winter), also in e. Atlantic (Robins et al. 1986).

*Habitat:* Marine.

*Risk Factors:* Medium to low productivity ( $T_{mat}$ ,  $T_{max}$ ), severe recruitment overfishing has led to collapse of stocks with the lowest increase rates ( $r$ ) (Myers et al. 1997a).

*Official Status:* Managed by FMP, U.S., regulated by DFO moratorium, Canada; *vulnerable*, COSEWIC.

*Status by DPS:* *Vulnerable*, Labrador and n.e. NF, s. Grand Banks, n. and s. Gulf of St. Lawrence, North Atlantic Fishery Organization Management Units have undergone 88.6–98.9% reduction in spawning stock biomass (Myers et al. 1997b) Although declines may have been mitigated in the n.e. DPSs by an oceanographic regime shift (J. Rice, Canada Department of Fisheries and Oceans, Ottawa, pers. comm.), the magnitude of these declines is cause for concern; other DPSs: *not at risk* (but overfished) (Mayo and O'Brien 2000).

#### *Theragra chalcogramma*

#### walleye pollock

*Range:* Coasts of n. Pacific from Japan to Bering Sea and to Carmel, cen. CA (Eschmeyer et al. 1983).

*Habitat:* Marine.

*Risk Factors:* Low productivity ( $T_{mat}$ ) (Megrey 1991; Love 1991), local populations vulnerable to overharvesting.

*Official Status:* Candidate List, U.S. (Puget Sound only).

*Status by DPS:* *Endangered*, s. Puget Sound, possibly extirpated, recreational catches exceeded 400,000 lbs./yr. from 1977 to 1986, the fishery collapsed in 1988, and recent trawl surveys have yielded no specimens (Palsson et al. 1997; Wright 1999b). N. Puget Sound DPS may be overharvested, but not at risk (Palsson et al. 1997). *Not at risk*, other DPSs (Dorn et al. 1999; Ianelli et al. 1999).

### Merlucciidae

#### *Merluccius productus*

#### Pacific hake

*Range:* Coast of Asia to AK, and to s. Baja Calif. and Gulf of Calif. (Eschmeyer et al. 1983).



Very low productivity is one factor in classifying the copper rockfish (*Sebastes caurinus*) as *vulnerable* in Puget Sound.

*Habitat:* Marine.

*Risk Factors:* Low productivity ( $T_{mat}$ ,  $T_{max}$ ) (Love 1991) locally concentrated spawning aggregations vulnerable to heavy overharvesting (Wright 1999b).

*Official Status:* Candidate List, U.S. (Puget Sound only).

*Status by DPS:* *Vulnerable*, s. Puget Sound, survey biomass estimates show decline from 45.1 million lbs. in 1983 to 1.1 million lbs. in 1998 (Palsson et al. 1997; Wright 1999b). High predation by pinnipeds may be preventing recovery despite stringent fishing regulations (Schmitt et al. 1996); other DPSs: *not at risk*.

**Aplocheilidae**

**Rivulus marmoratus mangrove rivulus**

*Range:* S. FL through West Indies, n. South America to Rio de Janeiro, Brazil (Taphorn 1980), Cuba, Jamaica, and Yucatán (Seegers 1984), coast of Venezuela, Bahamas: New Providence, Bimini, Andros Isl., Great Bahama Bank (Böhlke and Chaplin 1968), Grand Cayman and Little Cayman Isl. (Huehner et al. 1985).

*Habitat:* Salt marshes, mangrove swamps, salinity 20–35 ppt. (Huehner et al. 1985); found in burrows of great land crab (*Cardisoma guanhumi*) (Taylor 1989).

*Risk Factors:* Rare, habitat degradation, destruction of mangroves, and *Cardisoma*.

*Official Status:* Candidate List, U.S.

*Status by DPS:* *Vulnerable*, (FL) U.S. (Taylor 1993; Taylor et al. 1995); other DPSs outside U.S.: *not assessed*.

**Poeciliidae**

**Gambusia rhizophorae mangrove gambusia**

*Range:* S.E. FL, Florida Keys, n.w. Cuba, Havana (Getter 1980).

*Habitat:* Marine, salinity 13–53 ppt, red mangrove roots (Gilbert 1992a).

*Risk Factors:* Restricted range, loss of red mangrove habitat (Gilbert 1992a).

*Official Status:* None.

*Status by DPS:* *Vulnerable*, FL, U.S. (Gilbert 1992a).

**Cyprinodontidae**

**Fundulus jenkinsi Saltmarsh topminnow**

*Range:* Gulf of Mexico: Galveston Bay, TX, to Escambia Bay, FL; Perdido Bay, FL; East Bay, FL (Gilbert 1992b).

*Habitat:* Estuarine, tidal meanders, *Spartina* marshes, salinity 01–20 ppt (Thompson 1980).

*Risk Factors:* Endemic, habitat degradation, loss of *Spartina* and wetlands (Poss 1998), limited distribution (Gilbert 1992b).

*Official Status:* Candidate List, U.S.

*Status by DPS:* *Threatened*, FL (Gilbert 1992b); *vulnerable*, remainder of Gulf of Mexico populations (Thompson 1998).

**Atherinidae**

**Menidia conchorum key silverside**

*Range:* Key West to Long Key, FL (Gilbert 1992c).

*Habitat:* Brackish, shallow water (Duggins et al. 1986), black mangrove rhizomes (Gilbert 1992c).

*Risk Factors:* Endemic to Florida Keys, loss of habitat (black mangroves) (Gilbert 1992c).

*Official Status:* Candidate List, U.S.

*Status by DPS:* *Vulnerable*, FL, U.S. (Gilbert 1992c).

**Syngnathidae**

**Anarchopterus criniger fringed pipefish**

*Range:* S. FL, Bahamas to Brazil, Gulf of Mexico (Böhlke and Chaplin 1968).

*Habitat:* Marine, sea grass beds.

*Risk Factors:* Rare, more information needed to correctly assess stocks (Poss 1999). This species reported locally common in Florida Bay sea grass beds during the 1970s (Schmidt 1979). Seagrass beds degraded or destroyed (Schmidt 1979; Fourqurean and Robblee 1999).

*Official Status:* None.

*Status by DPS:* *Vulnerable*, Gulf of Mexico; other DPSs: *not assessed*.

Wydoski & Whitney/AFS Fish Slide catalog



The eulachon (*Thaleichthys pacificus*) spawns in vulnerable freshwater habitat.

**Hippocampus reidi**

**longsnout seahorse**

*Range:* Gulf of Mexico (eastern distribution s.w. FL and n.w. Cuba to Cape Hatteras); Caribbean; Colombia to Brazil, South America (Ginsburg 1933); Bahamas; Panama to Bermuda, West Indies (Böhlke and Chaplin 1968).

*Habitat:* Marine, seagrass beds.

*Risk Factors:* Rare, habitat degradation, seagrass beds in s. FL degraded or destroyed by increased freshwater influx from man-made canals (Fourqurean and Robblee 1999; T. Schmidt, pers. observ.).

*Official Status:* None.

*Status by DPS:* *Threatened*, U.S. (Fore and Schmidt 1974; Poss 1998; T. Schmidt, pers. observ.); other DPSs: *not assessed*.

**Hippocampus zosterae**

**dwarf seahorse**

*Range:* FL, U.S. from Biscayne Bay to Pensacola; Cuba; Bermuda; Bahamas (Böhlke and Chaplin 1968); Gulf of Mexico (Poss 1998).

*Habitat:* Marine, vegetated areas of eelgrass (*Zostera*) (Poss 1998) and turtlegrass (*Thalassia*) (Schmidt 1979).

*Risk Factors:* Rare, habitat degradation (*Zostera*), restricted habitat (Poss 1999). Locally common, Florida Bay seagrass beds (Schmidt 1979), loss of grassbeds (Fourqurean and Robblee 1999).

*Official Status:* None, U.S.

*Status by DPS:* *Vulnerable*, U.S.

**Microphis brachyurus**

**opossum pipefish**

*Range:* W. Atlantic from SC, U.S. to Bahamas, Caribbean isl., Gulf of Mexico (Böhlke and Chaplin 1968); e. Pacific



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Ocean, Pacific terminus of Panama Canal (Hildebrand 1939).

*Habitat:* Anadromous.

*Risk Factors:* Habitat degradation, dredging, isolated populations in n. Gulf of Mexico (rare) and Indian River Lagoon, FL, where a freshwater habitat vegetated with *Panicum* spp. and *Polygonum* spp. is polluted by seasonal herbicide treatment (Gilbert 1992d; Gilmore 1999). Juveniles mature offshore in *Sargassum* (Böhlke and Chaplin 1968).

*Official Status:* Candidate List, U.S.

*Status by DPS:* *Threatened*, U.S. N. Gulf of Mexico, Indian River Lagoon, FL (Gilbert 1992d; Gilmore 1999); other DPSs: *not assessed*.

### *Syngnathus affinis* Texas pipefish

*Range:* N. Gulf of Mexico, Corpus Christi Bay, TX (Dawson 1982), Grande Isle and Prien Lake, LA (Poss 1998).

*Habitat:* Estuarine, submerged aquatic vegetation.

*Risk Factors:* Endemic, rare, habitat degradation, destruction of submerged aquatic vegetation; fishing, shrimp-ing, dredging (Poss 1998), restricted range.

*Official Status:* None, U.S.

*Status by DPS:* *Endangered*, U.S.

Wydoski & Whitney/AFS Fish Slide catalog



The longfin smelt (*Spirinchus thaleichthys*) was formerly abundant in California.

**Scorpaenidae:** Most of the scorpaenids listed are from the Pacific (rockfishes) and are slow growing, late maturing, and long-lived with sporadic, infrequent recruitment. In addition, many species are resident with relatively small home ranges (Parker et al. 2000). Thus, rockfishes are inherently vulnerable to overfishing and stock collapse. This list contains a minimum number of Pacific rockfishes at risk. Many other rockfish DPSs may be at risk, but have not been assessed because of lack of sufficient time or data.

### *Sebastes alutus* Pacific ocean perch

*Range:* Japan and Bering Sea to La Jolla (s. CA); common from OR northward (Eschmeyer et al. 1983).

*Habitat:* Marine.

*Risk Factors:* Very low productivity ( $T_{max}$ ) (Love et al. in press).

*Official Status:* None.

*Status by DPS:* *Vulnerable*, WA and OR, 81–91% decline from overfishing (Ianelli and Zimmerman 1998); *not at risk*, AK (Heifetz et al. 1999; Ito et al. 1999); *not assessed*, Canada.

### *Sebastes auriculatus* brown rockfish

*Range:* S.E. AK to cen. Baja Calif. (Eschmeyer et al. 1983).

*Habitat:* Marine.

*Risk Factors:* Probable low to very low productivity ( $T_{max}$ ) (Love 1991).

*Official Status:* Candidate List, U.S. (Puget Sound only).

*Status by DPS:* *Vulnerable*, Puget Sound, long-term declines since mid-1980s, difficult to quantify because other rockfish species pooled in survey data (Barker 1998; Wright 1999b); other DPSs: *not assessed*.

### *Sebastes caurinus* copper rockfish

*Range:* N. Gulf of Alaska to cen. Baja Calif. (Eschmeyer et al. 1983).

*Habitat:* Marine.

*Risk Factors:* Very low productivity ( $T_{max}$ ) (Love 1991).

*Official Status:* Candidate List, U.S. (Puget Sound only)

*Status by DPS:* *Vulnerable*, Puget Sound, long-term decline since mid-1980s (Wright 1999b), spawner output declined by > 80% from 1979 to 1992 (WA Department of Fish and Wildlife 1997). *Not at risk*, AK (O'Connell et al. 1999); other DPSs: *not assessed*.

### *Sebastes crameri* dark blotched rockfish

*Range:* Bering Sea to near Santa Catalina Isl. (s. CA) (Eschmeyer et al. 1983).

*Habitat:* Marine.

*Risk factors:* Very low productivity ( $T_{max}$ ) (Love et al. in press).

*Official Status:* None.

*Status by DPS:* *Vulnerable*, WA, OR, CA, 77–89% decline (Rogers et al. 2000); other DPSs: *not assessed*.

### *Sebastes entomelas* widow rockfish

*Range:* S.E. AK to n. Baja Calif. (Eschmeyer et al. 1983).

*Habitat:* Marine.

*Risk Factors:* Very low productivity ( $T_{max}$ ) (Love et al. in press).

*Official Status:* None.

*Status by DPS:* *Vulnerable*, WA, OR, CA, 81–82% decline (Williams et al. 2000); *not at risk*, AK (Clausen and Heifetz 1999); Canadian DPSs: *not assessed*.

### *Sebastes fasciatus* Acadian redfish

*Range:* Iceland and w. Greenland to Gulf of St. Lawrence and Gulf of Maine (Robins et al. 1986).

*Habitat:* Marine, coastal.

*Risk Factors:* Low productivity ( $k$ ,  $T_{max}$ ,  $T_{mat}$ ) (Mayo 1993; Mayo 2000), vulnerable to overfishing.

*Official Status:* None.

*Status by DPS:* *Conservation dependent*, Gulf of Maine, 99% decline from 1968 to 1984, population recovery in progress under FMP (Mayo 2000); other DPSs: *not assessed*.

### *Sebastes levis* cowcod

*Range:* Cen. CA to cen. Baja Calif. (Eschmeyer et al. 1983).

*Habitat:* Marine.

*Risk Factors:* Very low productivity ( $T_{max}$ ) (Love et al. in press).

*Official Status:* None.

*Status by DPS:* *Vulnerable*, U.S., 91–97% decline (Butler et al. 1999).

**Sebastes maliger** **quillback rockfish**  
*Range:* Gulf of Alaska to cen. CA (Eschmeyer et al. 1983).  
*Habitat:* Marine.  
*Risk Factors:* Very low productivity ( $T_{max}$ ) (PFMC 1999).  
*Official Status:* Candidate List, U.S. (Puget Sound only).  
*Status by DPS:* *Vulnerable*, Puget Sound, long-term decline (Barker 1998; Wright 1999b); *not at risk*, AK (O'Connell et al. 1999); other DPSs: *not assessed*.

**Sebastes melanops** **black rockfish**  
*Range:* Amchitka Isl. (Aleutian Isl.) to San Miguel Isl. (s. CA.) (Eschmeyer et al. 1983).  
*Habitat:* Marine.  
*Risk Factors:* Low to very low productivity ( $T_{max}$ ) (Love 1991).  
*Official Status:* None.  
*Status by DPS:* *Vulnerable*, Puget Sound, long-term decline, has become rare (Barker 1998; Crawford 1999; Wright 1999b); *not at risk*, AK; other DPSs: *not assessed*.

**Sebastes nigrocinctus** **tiger rockfish**  
*Range:* S.E. AK to cen. CA (Eschmeyer et al. 1983).  
*Habitat:* Marine.  
*Risk Factors:* Probable low to very low productivity ( $T_{max}$ ) (Love et al. in press).  
*Official Status:* None.  
*Status by DPS:* *Vulnerable*, Puget Sound, long-term decline since mid-1980s (Wright 1999b), has virtually disappeared from recreational catches (Barker 1998); *not at risk*, AK (O'Connell et al. 1999); other DPSs: *not assessed*.

**Sebastes paucispinis** **bocaccio**  
*Range:* Kodiak Isl., AK, to cen. Baja Calif. (Eschmeyer et al. 1983).  
*Habitat:* Marine.  
*Risk Factors:* Very low productivity ( $T_{max}$ ) (Love et al. in press).  
*Official Status:* Candidate List, U.S.  
*Status by DPS:* *Vulnerable*, WA, OR, CA, 96–98% decline (McCall et al. 1999); other DPSs: *not assessed*.

**Sebastes pinniger** **canary rockfish**  
*Range:* S.E. AK to n. Baja Calif. (Eschmeyer et al. 1983).  
*Habitat:* Marine.  
*Risk Factors:* Very low productivity ( $T_{max}$ ) (Love et al. in press).  
*Official Status:* None.  
*Status by DPS:* *Vulnerable*, WA, CA, OR, 77–93% decline (Stock Assessment Team 1999); *not at risk*, AK (O'Connell et al. 1999); other DPSs: *not assessed*.

**Sebastes ruberrimus** **yelloweye rockfish**  
*Range:* Gulf of Alaska to n. Baja Calif. (Eschmeyer et al. 1983).  
*Habitat:* Marine.  
*Risk Factors:* Very low productivity ( $T_{max}$ ) (Love 1991).  
*Official Status:* None.  
*Status by DPS:* *Vulnerable*, Puget Sound, long-term decline (Wright 1999b), has virtually disappeared from recreational catches (Barker 1998); *not at risk*, AK (O'Connell et al. 1999); other DPSs: *not assessed*.

**Sebastolobus alascanus** **shortspine thornyhead**  
*Range:* Bering Sea to n. Baja Calif. (Eschmeyer et al. 1983).  
*Habitat:* Marine.  
*Risk Factors:* Very low productivity ( $T_{max}$ ) (Love et al. in press).  
*Official Status:* None.  
*Status by DPS:* *Vulnerable*, WA, OR, CA, 73% decline (Rogers et al. 1998); *not at risk*, AK (Ianelli and Gaichas 1999); other DPSs: *not assessed*.

**Polyprionidae**  
**Stereolepis gigas** **giant seabass**  
*Range:* Humboldt Bay, CA, to Bahia Magdalena (s.w. Baja Calif.) and n. Gulf of Calif.; rare n. of s. CA (Eschmeyer et al. 1983; Thompson et al. 2000).  
*Habitat:* Marine, coastal.  
*Risk Factors:* Large species with probable low to very low productivity ( $k, T_{max}$ ).  
*Official Status:* None, U.S.; *protected*, CA.  
*Status by DPS:* *Threatened*, Gulf of Calif., very rare (E. Sala, pers. observ.); *vulnerable*, U.S.

**Hexagrammidae**  
**Ophiodon elongatus** **lingcod**  
*Range:* Kodiak Isl., AK, to n. Baja Calif.; possibly Bering Sea (Eschmeyer et al. 1983).  
*Habitat:* Marine.  
*Risk Factors:* Low productivity ( $T_{max}, k$ ) (Smith and McFarlane 1990; Adams et al. 1999).  
*Official Status:* None.  
*Status by DPS:* *Vulnerable*, WA, OR, CA, 92.5% decline (Adams et al. 1999); other DPSs: *not assessed*.

**Centropomidae**  
**Centropomus parallelus** **fat snook**  
*Range:* S. FL, West Indies, and Mexico to Brazil.  
*Habitat:* Amphidromous, marine to freshwater, tropical.  
*Risk Factors:* Restricted in U.S. to freshwater tributaries of Indian River Lagoon, FL and upper Ten Thousand Isl. to n.e. Florida Bay, FL. Extensive release of water from Lake Okeechobee into St. Lucie R. by U.S. Army Corps of Engineers (USACE) and South Florida Water Management District (SFWMD) has changed salinity regimes, increased fish disease, created toxic dinoflagellate blooms, caused extensive fish mortality, and eradicated important nursery grounds; also toxic chemical spills (Gilmore 1995).  
*Official Status:* None.  
*Status by DPS:* *Vulnerable*, U.S., Indian River Lagoon and upper Ten Thousand Isl. to n.e. Florida Bay, FL, populations threatened by habitat degradation (Gilmore 1995; Fourqurean and Robblee 1999; T. Schmidt, NPS data and pers. observ.); other DPSs: *not assessed*.

**Centropomus pectinatus** **tarpon snook**  
*Range:* S. FL, West Indies, and Mexico to Brazil.  
*Habitat:* Amphidromous, marine to freshwater, tropical.  
*Risk Factors:* Restricted in U.S. to freshwater tributaries of Indian River Lagoon, FL, and upper Ten Thousand Isl.,

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FL (T. Schmidt, pers. observ.) Extensive release of water from Lake Okeechobee into St. Lucie R. by U.S. Army Corps of Engineers (USACE) and South Florida Water Management District (SFWMD) has changed salinity regimes, increased fish disease, created toxic dinoflagellate blooms, caused extensive fish mortality, and eradicated important nursery grounds; also toxic chemical spills (Gilmore 1995).

*Official Status:* None.

*Status by DPS:* *Vulnerable*, U.S., Indian River Lagoon and upper Ten Thousand Isl., FL, populations threatened by habitat degradation (Gilmore 1995; Fourqurean and Robblee 1999; T. Schmidt, pers. observ.); other DPSs: *not assessed*.

### Serranidae

#### *Dermatolepis inermis* **marbled grouper**

*Range:* W. Atlantic: NC throughout Caribbean, and Gulf of Mexico to Rio de Janeiro, Brazil (Heemstra and Randall 1993).

*Habitat:* Marine.

*Risk Factors:* Rare, probably low productivity, "secretive," little known about biology or habitat (Heemstra and Randall 1993; Huntsman et al. 1999).

*Official Status:* None.

*Status by DPS:* *Vulnerable*, U.S.; other DPSs: *not assessed*.

#### *Epinephelus drummondhayi* **speckled hind**

*Range:* W. Atlantic: NC to Florida Keys, n. and e. Gulf of Mexico, Bermuda (Heemstra and Randall 1993).

*Habitat:* Marine, offshore (60–120m), rocky bottoms.

*Risk Factors:* Low productivity ( $k$ ,  $T_{max}$ ), protogynous (Ault et al. 1998), vulnerable to commercial and recreational overfishing (Huntsman et al. 1999).

*Official Status:* Candidate List, U.S.

*Status by DPS:* *Endangered*, U.S., steady and drastic decline in abundance, males rare (G. R. Huntsman, pers. observ.).

#### *Epinephelus flavolimbatus* **yellowedge grouper**

*Range:* W. Atlantic: NC to s. Brazil, Gulf of Mexico, Caribbean (Heemstra and Randall 1993).

*Habitat:* Marine, rocky bottoms.

*Risk Factors:* Rare, probable low productivity, protogynous, local spawning aggregations (R. G. Gilmore, pers. observ.), vulnerable to overfishing (Heemstra and Randall 1993).

*Official Status:* None.

*Status by DPS:* *Endangered*, U.S. Atlantic populations may be extirpated, status of Gulf of Mexico DPS uncertain (Huntsman et al. 1999); other DPSs: *not assessed*.

#### *Epinephelus itajara* **jewfish**

*Range:* W. Atlantic: FL to s. Brazil, Gulf of Mexico, Caribbean; e. Atlantic: Senegal to Congo; e. Pacific: Gulf of Calif. to Peru (Heemstra and Randall 1993).

*Habitat:* Marine, coral and rock reefs, mangrove lagoons (juveniles).

*Risk Factors:* Low productivity ( $k$ ,  $T_{max}$ ), protogynous (Ault et al. 1998), localized spawning aggregations, long-

lived, vulnerable to commercial and recreational overfishing. Approx. one-fourth of localized spawning sites extirpated (Sadovy and Eklund 1999).

*Official Status:* Candidate List, U.S., *protected* in FL and U.S. Atlantic federal waters by FMP (South Atlantic and Gulf of Mexico Fishery Management Councils).

*Status by DPS:* *Endangered*, Gulf of Calif., very rare (E. Sala, pers. observ.; L. Findley, pers. observ.); *conservation dependent*, U.S., Atlantic and Gulf of Mexico, uncommon (Huntsman et al. 1999), but recovery under FMP (A. M. Eklund, pers. observ.); other DPSs: *not assessed*.

#### *Epinephelus nigritus* **warsaw grouper**

*Range:* W. Atlantic: MA to Rio de Janeiro, Brazil throughout Gulf of Mexico, Cuba, Trinidad (Heemstra and Randall 1993).

*Habitat:* Marine, rocky bottom.

*Risk Factors:* Very low productivity ( $k$ ,  $T_{max}$ ) (Ault et al. 1998), rare, protogynous, vulnerable to overfishing (Heemstra and Randall 1993).

*Official Status:* Candidate List, U.S.

*Status by DPS:* *Endangered*, U.S., now very rare, only small individuals observed (Huntsman et al. 1999); other DPSs: *not assessed*.

#### *Epinephelus niveatus* **snowy grouper**

*Range:* W. Atlantic: MA to s. Brazil, Gulf of Mexico, Caribbean, Bermuda (Heemstra and Randall 1993).

*Habitat:* Marine, offshore, rocky bottom (30–525 m).

*Risk Factors:* Low productivity ( $k$ ,  $T_{max}$ ) (Ault et al. 1998), protogynous, spawning aggregations, vulnerable to extirpation.

*Official Status:* None.

*Status by DPS:* *Vulnerable*, U.S. populations severely depleted (Huntsman et al. 1999; Huntsman, pers. observ.), percent of males in population have declined significantly (Wyanski et al. 2000); other DPSs: *not assessed*.

#### *Epinephelus striatus* **Nassau grouper**

*Range:* W. Atlantic: Bermuda, Bahamas, Caribbean to s. Brazil, Yucatán Peninsula (Heemstra and Randall 1993), Gulf of Mexico (Böhlke and Chaplin 1968).

*Habitat:* Marine, coral reefs.

*Risk Factors:* Low productivity ( $k$ ,  $T_{max}$ ), localized spawning aggregations, vulnerable to commercial and recreational overfishing.

*Official Status:* Candidate List, U.S., *protected* in FL, and s. Atlantic federal waters by FMP (SAFMC, GMFMC).

*Status by DPS:* *Threatened*, U.S., Mexico, once very common but, now rare (Huntsman et al. 1999). Approx. one-third of localized spawning sites extirpated (Sadovy and Eklund 1999). Numbers in some spawning aggregations reduced by 90% in Mexico to Guatemala (E. Sala, pers. observ.). Other DPSs: *not assessed*.

#### *Hypoplectrus gemma* **blue hamlet**

*Range:* Florida Keys to s. cen. FL (Robins et al. 1986).

*Habitat:* Marine, coral reefs, rocky bottoms.

*Risk Factors:* Endemic, vulnerable habitat.

*Official Status:* None.

*Status by DPS:* *Vulnerable*, U.S., endemic to Florida Keys, Dry Tortugas, and rock-reef sites on cen. Atlantic coast of FL, common in places (T. Schmidt and R. G. Gilmore, pers. observ.) but habitat threatened by human activities.

***Mycteroperca bonaci*** **black grouper**

*Range:* W. Atlantic: MA, Bermuda to s. Brazil, s. Gulf of Mexico, Florida Keys, Bahamas, Cuba, Caribbean (Heemstra and Randall 1993).

*Habitat:* Marine, rocky bottoms, coral reefs.

*Risk Factors:* Low productivity (k,  $T_{max}$ ), protogynous (Ault et al. 1998), heavily fished, spawning aggregations vulnerable to overfishing (Heemstra and Randall 1993).

*Official Status:* None.

*Status by DPS:* *Vulnerable*, U.S., Florida Keys once common, but now uncommon (Huntsman et al. 1999); Mexico, large decline since 1970s, spawning aggregations may be gone (E. Sala, pers. observ.).

***Mycteroperca interstitialis*** **yellowmouth grouper**

*Range:* W. Atlantic: Gulf of Mexico, Bermuda, Caribbean and s. Brazil (Heemstra and Randall 1993).

*Habitat:* Marine, coral reefs, rocky bottoms.

*Risk Factors:* Uncommon, low productivity (k,  $T_{max}$ ) (Ault et al. 1998), probable protogynous, vulnerable to overfishing, similar in appearance to more common *M. phenax* (Huntsman et al. 1999).

*Official Status:* None.

*Status by DPS:* *Vulnerable*, U.S., similar species taken together in fisheries, the less-abundant *M. interstitialis* could be extirpated while more abundant *M. phenax* persists in the fishery (Huntsman et al. 1999).

***Mycteroperca jordani*** **gulf grouper**

*Range:* E. Pacific: La Jolla, CA (rare) to Mazatlán (s. Sinaloa), Mexico (Heemstra and Randall 1993).

*Habitat:* Marine, rock reefs (5–30m), kelp beds.

*Risk Factors:* Large species with probable low productivity ( $T_{max}$ , k), spawning aggregations heavily fished (E. Sala, pers. observ.) and subject to small-scale commercial and recreational overfishing in general (L. Findley, pers. observ.), small range.

*Official Status:* *Protected*, CA.

*Status by DPS:* *Vulnerable*, Gulf of Calif., rare in s. Gulf, still seen but not abundant in n. Gulf (E. Sala and L. Findley, pers. observ.).

***Mycteroperca microlepis*** **gag**

*Range:* W. Atlantic: NC to Yucatán Peninsula, Gulf of Mexico, e. Brazil (Heemstra and Randall 1993).

*Habitat:* Estuarine (juveniles), marine (adults), offshore 40–100m, rocky bottoms.

*Risk Factors:* Low productivity (k,  $T_{max}$ ) (Ault et al. 1998), protogynous, spawning aggregations, vulnerable to overfishing (Huntsman et al. 1999).

*Official Status:* None.

*Status by DPS:* *Vulnerable*, U.S., male biomass in Atlantic reduced from 20% to 6% from 1982 to 1995 (Huntsman et al. 1999; McGovern et al. 1998); other DPSs: *not assessed*.

***Mycteroperca phenax*** **scamp**

*Range:* W. Atlantic: NC to Key West, FL; Gulf of Mexico and s. shore of Caribbean (Heemstra and Randall 1993).

*Habitat:* Marine, rocky bottoms (Heemstra and Randall 1993).

*Official Status:* None.

*Risk Factors:* Low productivity (k,  $T_{max}$ ) (Ault et al. 1998), protogynous, specific habitat, vulnerable to overfishing.

*Status by DPS:* *Vulnerable*, U.S., overfished (Huntsman et al. 1999), male biomass declined from 34% to 21% from the mid-1980s to mid-1990s (Harris et al. in press), species demography and vulnerability to population collapse dictate close monitoring; other DPSs: *not assessed*.

***Mycteroperca prionura*** **sawtail grouper**

*Range:* E. Pacific: n. Gulf of Calif. to s. Jalisco, Mexico (Heemstra and Randall 1993; Thompson et al. 2000).

*Habitat:* Marine, rock reefs (8–40m).

*Risk Factors:* Rare, large species, probable low productivity (k,  $T_{max}$ ), probable protogynous, species aggregations vulnerable to overfishing (Thompson et al. 2000; L. Findley and E. Sala, pers. observ.), small range.

*Official Status:* None, U.S.

*Status by DPS:* *Vulnerable*, Mexico.

***Mycteroperca xenarcha*** **broomtail grouper**

*Range:* E. Pacific: n. CA (rare) and cen. Gulf of Calif. to Peru (Thompson et al. 2000).

*Habitat:* Marine, estuarine, mangrove swamps.

*Risk Factors:* Large species, probable low productivity (k,  $T_{max}$ ), probably aggregates to spawn, thus vulnerable to overexploitation.

*Official Status:* *Protected*, CA.

*Status by DPS:* *Vulnerable*, CA, Mexico, little information available on status of this large uncommon (perhaps now rare) species (L. Findley, pers. observ.). Other DPSs: *not assessed*.

**Sciaenidae**

***Bairdiella batabana*** **blue croaker**

*Range:* Bay of Campeche, Mexico; e. and w. FL, Greater Antilles (Chao 1978), Cuba, Puerto Rico, Virgin Islands, s. Florida Keys and Florida Bay (Schmidt 1979; Poss 1998).

*Habitat:* Marine, high salinities > 30 ppt.

*Risk Factors:* Rare, restricted in U.S. to s. FL, restricted to clean, sheltered waters with sea grass beds (Robins et al. 1986). Populations threatened by massive sea grass die-off and increased turbidity altered by freshwater inflow from upland man-made canals (Fourqurean and Robblee 1999; T. Schmidt, NPS data).

*Official Status:* None

*Status by DPS:* *Vulnerable*, FL (Poss 1998); other DPSs: *not assessed*.

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### **Bairdiella sanctaeluciae** **striped croaker**

*Range:* Caribbean Sea, Gulf of Campeche, Greater and Lesser Antilles (Gilmore and Snelson 1992), e. cen. FL but not s. of Jupiter Inlet and n. of Sebastian Inlet.

*Habitat:* Marine, rocky bottoms with algal growth (Gilmore and Snelson 1992).

*Risk Factors:* Habitat degradation: dredging, range restricted in FL to cen. e. coast of FL (Gilmore and Snelson 1992). Offshore dumping and reef habitat burial, overgrazing by *Echinometra* sea urchins.

*Official Status:* None.

*Status by DPS:* *Vulnerable*, FL (Gilmore and Snelson 1992); other DPSs: *not assessed*.

### **Cynoscion othonopterus** **Gulf corvina**

*Range:* N. Gulf of Calif., Mexico (Chao 1995).

*Habitat:* Marine, estuarine.

*Risk Factors:* Endemic, probable low productivity, large species subject to heavy overharvesting especially when aggregated for spawning (L. Findley and E. Sala, pers. observ.). Loss of estuarine nursery habitat because of multiple water diversions in Colorado R. in the U.S.

*Official Status:* None.

*Status by DPS:* *Vulnerable*, large recent decline in population (L. Findley and E. Sala, pers. observ.).

### **Totoaba macdonaldi** **totoaba**

*Range:* N. Gulf of Calif., Mexico.

*Habitat:* Marine, estuarine.

*Risk Factors:* Endemic, low productivity, very large species formerly subject to heavy overharvesting by gillnet fisheries (Cisneros-Mata et al. 1995), no evidence of recovery as yet, heavy bycatch of juveniles in shrimp fishery continues (L. Findley, pers. observ.). Loss of estuarine spawning-nursery habitat because of multiple water diversions in Colorado R. in the U.S.

*Official Status:* *Endangered*, and a "specially protected species" in Mexico (also listed as endangered in U.S. where it does not occur).

*Status by DPS:* *Endangered*.

### **Labrisomidae**

#### **Starksia starcki** **key blenny**

*Range:* Florida Keys, Belize, Honduras (Robins et al. 1986).

*Habitat:* Coral reefs, surge channels with high relief in 6–19 m.

*Risk Factors:* Very rare.

*Official Status:* None.

*Status by DPS:* *Vulnerable*, U.S., found only in Florida Keys and Dry Tortugas where very rare, may be cryptic and elusive (T. Schmidt, pers. observ.). Other DPSs: *not assessed*.

### **Eleotridae**

#### **Gobiomorus dormitor** **bigmouth sleeper**

*Range:* E. FL to Cuba, Jamaica, Puerto Rico, Martinique, Cen. America to Surinam; s. Gulf of Mexico (TX to Yucatán), Rio Grande and Rio Tamesi drainages, Mexico (Gilmore 1992a).

*Habitat:* Amphidromous, marine to freshwater.

*Risk Factors:* Restricted in U.S. to freshwater tributaries of Indian River Lagoon, FL. Extensive release of water from Lake Okeechobee into St. Lucie R. by the USACE and the SFWMD has changed salinity regimes, increased fish disease, created toxic dinoflagellate blooms, caused extensive fish mortality, and eradicated important nursery grounds; also toxic chemical spills here (Gilmore 1992a, 1995).

*Official Status:* None.

*Status by DPS:* *Threatened*, FL (Gilmore 1992a). Other DPSs: *not assessed*.

### **Gobiidae**

#### **Awaous banana** **river goby**

*Range:* Savannah R. of SC, e. and w. FL to Venezuela, Lesser and Greater Antilles (Gilmore 1992b).

*Habitat:* Amphidromous, marine to freshwater, tropical.

*Risk Factors:* Mainly restricted in U.S. to freshwater tributaries of Indian River Lagoon, FL. Extensive release of water from Lake Okeechobee into St. Lucie R. by USACE and the SFWMD has changed salinity regimes, increased fish disease, created toxic dinoflagellate blooms, caused extensive fish mortality, and eradicated important nursery grounds; also toxic chemical spills here (Gilmore 1992b, 1995).

*Official Status:* None.

*Status by DPS:* *Threatened*, U.S. (Gilmore 1992b).

#### **Ctenogobius pseudofasciatus** **slashcheek goby**

*Range:* Costa Rica, Panama, Trinidad, Suriname; e. FL: Loxahatchee R., St. Lucie R. and Sebastian Creek (Gilmore 1992c).

*Habitat:* Estuarine, freshwater salinity 0–13 ppt., tropical.

*Risk Factors:* Restricted in U.S. to freshwater tributaries of Indian River Lagoon, FL. Extensive release of water from Lake Okeechobee into St. Lucie R. by USACE and the SFWMD has changed salinity regimes, increased fish disease, created toxic dinoflagellate blooms, caused extensive fish mortality, and eradicated important nursery grounds; also toxic chemical spills here (Gilmore 1992c, 1995).

*Official Status:* None.

*Status by DPS:* *Threatened*, FL (Gilmore 1992c).

#### **Eucylogobius newberryi** **tidewater goby**

*Range:* Smith R. (northernmost CA) to Agua Hedionda Lagoon (s. CA).

*Habitat:* Estuarine.

*Risk Factors:* Endemic, habitat loss and degradation of coastal wetlands, ditch and fill, freshwater diversion, grazing, breach of coastal lagoons and flood control (Lafferty et al. 1996).

*Official Status:* *Endangered*, U.S.

*Status by DPS:* *Endangered*, U.S., recolonization within the metapopulation may provide way to recovery if habitat improved (Lafferty et al. 1996).

#### **Gobionellus atripinnis** **blackfin goby**

*Range:* Rio Chiquito, Veracruz, n. to Brownsville, TX (Poss 1998).

*Habitat:* Brackish, freshwater (Poss 1998).

**Risk Factors:** Habitat degradation, decline in water quality, little information about habitat, stocks and life history (Poss 1999), small range.

**Official Status:** None.

**Status by DPS:** *Vulnerable*, U.S. (Poss 1998). Other DPSs: *not assessed*.

**Gobionellus stigmaturus spottail goby**

**Range:** S.E. FL (Gilmore 1992d), Bermuda, Cuba, Belize and Panama (Pezold 1984).

**Habitat:** Marine, tropical, shallow inlet areas (~1 m), sea grass beds (*Syringodium filiforme*, *Halodule wrightii*), inter-barrier island cuts where sediment allows burrow formation. Migrates between sand burrows and grass beds (Gilmore 1992d, 1995).

**Risk Factors:** Habitat degradation, decline in water quality from inlet dredging (Gilmore 1992d).

**Official Status:** None.

**Status by DPS:** *Vulnerable*, only populations in U.S. in e. cen. FL and Florida Keys, habitat degraded by inlet dredging (Gilmore 1992d). Other DPSs: *not assessed*.

**Nes longus orangespotted goby**

**Range:** Bermuda to e. FL, Bahamas to Panama and Venezuela (Robins et al. 1986).

**Habitat:** Marine, tropical, inlet cuts, burrows into sediment with commensal alpheid shrimps (Böhlke and Chaplin 1968).

**Risk Factors:** Destruction of limited specialized habitat by inlet dredging (Gilmore 1995).

**Official Status:** None.

**Status by DPS:** *Vulnerable*, only populations in U.S. occur in cuts and inlets from S. Indian River Lagoon, FL, through Florida Keys, threatened by inlet dredging (Gilmore 1992d). Other DPSs: *not assessed*.

**Acanthuridae**

**Acanthurus randalli gulf surgeonfish**

**Range:** E. Gulf of Mexico and occasional to Florida Keys (Robins et al. 1986).

**Habitat:** Coastal.

**Risk Factors:** Endemic, uncommon (Kaufman and Strycky 1990).

**Official Status:** None.

**Status by DPS:** *Vulnerable*, little data on distribution and abundance.

**Pleuronectidae**

**Hippoglossus hippoglossus Atlantic halibut**

**Range:** W. Atlantic: Greenland to VA, also in e. Atlantic.

**Habitat:** Marine, coastal to upper slope, boreal, demersal.

**Risk Factors:** Very large, low to very low productivity ( $k$ ,  $T_{max}$ ) (Beverton and Holt 1959; Pauly 1978b; Haug 1990), heavily overfished.

**Official Status:** None.

**Status by DPS:** *Threatened*, U.S., once common, now very rare, U.S. populations remnant, heavily overfished in 19th century with no recovery (Bigelow and Schroeder 1953;



Author Musick with an Atlantic halibut (*Hippoglossus hippoglossus*) caught on the NMFS research vessel Albatross IV in 1964.

Brodziak 2000). U.S. population in deep water may be sustained by spawning from Canadian population to the northeast, may now be a sink for a larger metapopulation (Brodziak 2000); *vulnerable*, Canada, Maritimes; *not at risk*, Grand Banks (J. Rice, pers. comm.).

**Analysis of risk factors**

We recognized 82 species and subspecies of marine fishes which included DPSs at least vulnerable to extirpation in North American waters. Many of these are vulnerable to more than one risk factor (Table 3). Our analyses of risk factors shows that life history limitations (51 species or subspecies) were by far, the most important, followed by habitat degradation (33 species or subspecies). Twelve species each are listed as endemic (or with small range) and/or as rare. Virtually all species that scored in these two categories are also vulnerable because of life history limitations or habitat degradation or both. Twenty-two species could be considered to be at least *vulnerable* to global extinction, because all of their DPSs were found to be at risk or because some species were comprised of one DPS, whose entire range was included in the assessment (Appendix 1).

Among groups that are particularly vulnerable because of life history limitations were 14 scorpaenids, 13 serranids (mostly large species), 11 elasmobranchs, 5 sturgeons, and small numbers in other families. The vulnerability of these major groups to extraordinary mortality because of their life history constraints has been recently reviewed in some detail (Birstien 1993; Musick 1999b; Coleman et al. 2000; Musick et al. 2000a; Musick et al. 2000b; Parker et al. 2000). Most species that are vulnerable because of life history limitations are large (> 50 cm TL) in size. Probably the greatest threat to these species with low productivity are mixed species fisheries, where more highly productive species continue to drive the fishery, while those with low productivity are reduced to stock collapse or extirpation (Musick 1999b).

Among those groups identified to be vulnerable because of habitat destruction or degradation, 18 are anadromous (ascending from the sea into freshwater to

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Table 3. Summary of taxas and factors that place them at risk. Risk categories are noted for each specie in parenthesis, species with multiple risk categories had multiple DPSS.

Scientific name	Common name	Rarity	Small range and endemics	Vulnerable habitat	Life history limitations	Other
Rhincodontidae <i>Rhincodon typus</i>	whale shark (CD)	x			x	
Odontaspidae <i>Odontaspis taurus</i>	sand tiger shark (V)				x	
Cetorhinidae <i>Cetorhinus maximus</i>	basking shark (CD,V)				x	
Lamnidae <i>Carcharodon carcharias</i>	white shark (CD)				x	
Carcharhinidae <i>Carcharhinus obscurus</i> <i>Carcharhinus signatus</i>	dusky shark (V) night shark (V)				x x	
Pristidae <i>Pristis pectinata</i> <i>Pristis perotteti</i>	smalltooth sawfish (E) largetooth sawfish (E)	x x			x x	
Rajidae <i>Amblyraja radiata</i> <i>Dipturus binoculata</i> <i>Dipturus laevis</i>	thorny skate (V) big skate (V) barndoor skate (V)				x x x	
Acipenseridae <i>Acipenser brevirostrum</i> <i>Acipenser medirostris</i> <i>Acipenser oxyrinchus desotoi</i> <i>Acipenser oxyrinchus oxyrinchus</i> <i>Acipenser transmontanus</i>	shortnose sturgeon (E,T,CD) green sturgeon (E,V) gulf sturgeon (E,T) Atlantic sturgeon (E,T,CD) white sturgeon (E,T,V,CD)			x x x x x	x x x x x	
Clupeidae <i>Alosa alabamae</i> <i>Clupea pallasii</i>	Alabama shad (V) Pacific herring (V)			x		x
Osmeridae <i>Hypomesus transpacificus</i> <i>Spirinchus thaleichthys</i> <i>Thaleichthys pacificus</i>	delta smelt (T) longfin smelt (T,V) eulachon (T,V)		x	x x x		x
Salmonidae <i>Salmo salar</i>	Atlantic salmon (E,T,V)			x		x
Gadidae <i>Gadus macrocephalus</i> <i>Gadus morhua</i> <i>Theragra chalcogramma</i>	Pacific cod (V) Atlantic cod (V) walleye pollock (E)				x x	x x x
Merlucciidae <i>Merluccius productus</i>	Pacific hake (V)					x
Aplocheilidae <i>Rivulus marmoratus</i>	mangrove rivulus (V)			x		
Poeciliidae <i>Gambusia rhizophorae</i>	mangrove gambusia (V)		x	x		
Cyprinodontidae <i>Fundulus jenkinsi</i>	saltmarsh topminnow (T,V)	x	x	x		
Atherinidae <i>Menidia conchorum</i>	key silverside (V)		x	x		
Syngnathidae <i>Anarchopterus criniger</i> <i>Hippocampus reidi</i> <i>Hippocampus zosterae</i> <i>Microphis brachyurus</i> <i>Syngnathus affinis</i>	fringed pipefish (V) longsnout seahorse (T) dwarf seahorse (V) opossum pipefish (T) Texas pipefish (E)	x x x x		x x x x x		

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Table 3. continued.

Scientific name	Common name	Rarity	Small range and endemics	Vulnerable habitat	Life history limitations	Other
Scorpaenidae						
<i>Sebastes aulutus</i>	Pacific ocean perch (V)				x	
<i>Sebastes auriculatus</i>	brown rockfish (V)				x	
<i>Sebastes caurinus</i>	copper rockfish (V)				x	
<i>Sebastes crameri</i>	darkblotched rockfish (V)				x	
<i>Sebastes entomelas</i>	widow rockfish (V)				x	
<i>Sebastes fasciatus</i>	Acadian redfish (CD)				x	
<i>Sebastes levis</i>	cowcod (V)				x	
<i>Sebastes maliger</i>	quillback rockfish (V)				x	
<i>Sebastes melanops</i>	black rockfish (V)				x	
<i>Sebastes nigrocinctus</i>	tiger rockfish (V)				x	
<i>Sebastes paucispinis</i>	bocaccio (V)				x	
<i>Sebastes pinniger</i>	canary rockfish (V)				x	
<i>Sebastes ruberrimus</i>	yelloweye rockfish (V)				x	
<i>Sebastolobus alascanus</i>	shortspine thornyhead (V)				x	
Polyprionidae						
<i>Stereolepis gigas</i>	giant seabass (V, T)				x	
Hexagrammidae						
<i>Ophiodon elongatus</i>	lingcod (V)				x	
Centropomidae						
<i>Centropomus parallelus</i>	fat snook (V)			x		
<i>Centropomus pectinatus</i>	tarpon snook (V)			x		
Serranidae						
<i>Dermatolepis inermis</i>	marbled grouper (V)	x			x	
<i>Epinephelus drummondhayi</i>	speckled hind (E)				x	
<i>Epinephelus flavolimbatus</i>	yellowedge grouper (E)				x	
<i>Epinephelus itajara</i>	jewfish (E, CD)				x	
<i>Epinephelus nigritus</i>	warsaw grouper (E)				x	
<i>Epinephelus niveatus</i>	snowy grouper (V)				x	
<i>Epinephelus striatus</i>	Nassau grouper (T)				x	
<i>Hypoplectrus gemma</i>	blue hamlet (V)		x		x	
<i>Mycteroperca bonaci</i>	black grouper (V)				x	
<i>Mycteroperca interstitialis</i>	yellowmouth grouper (V)				x	
<i>Mycteroperca jordani</i>	gulf grouper (V)		x		x	
<i>Mycteroperca microlepis</i>	gag (V)				x	
<i>Mycteroperca phenax</i>	scamp (V)				x	
<i>Mycteroperca prionura</i>	sawtail grouper (V)		x		x	
<i>Mycteroperca xenarcha</i>	broomtail grouper (V)				x	
Sciaenidae						
<i>Bairdiella batabana</i>	blue croaker (V)			x		
<i>Bairdiella sanctaeluciae</i>	striped croaker (V)			x		
<i>Cynoscion othonopterus</i>	Gulf corvina (V)		x	x	x	
<i>Totoaba macdonaldi</i>	totoaba (E)		x	x	x	
Clinidae						
<i>Starksia starcki</i>	key blenny (V)	x				
Eleotridae						
<i>Gobiomorus dormitor</i>	bigmouth sleeper (T)			x		
Gobiidae						
<i>Awaous banana</i>	river goby (T)			x		
<i>Ctenoobius pseudofasciatus</i>	slashcheek goby (T)			x		
<i>Eucyclogobius newberryi</i>	tidewater goby (E)		x	x		
<i>Gobionellus atripinnis</i>	blackfin goby (V)			x		
<i>Gobionellus stigmaturus</i>	spottail goby (V)			x		
<i>Nes longus</i>	orangespotted goby (V)			x		
Acanthuridae						
<i>Acanthurus randalli</i>	gulf surgeonfish (V)	x	x			
Pleuronectidae						
<i>Hippoglossus hippoglossus</i>	Atlantic halibut (T, V)	x			x	
<b>Totals</b>		<b>12</b>	<b>12</b>	<b>32</b>	<b>52</b>	<b>7</b>



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### Appendix 1. Species vulnerable to global extinction.

<i>Amblyraja radiata</i>	<i>Menidia conchorum</i>
<i>Dipturus binoculata</i>	<i>Syngnathus affinis</i>
<i>Dipturus laevis</i>	<i>Sebastes levis</i>
<i>Acipenser brevirostrum</i>	<i>Sebastes paucispinis</i>
<i>A. medirostris</i>	<i>Epinephelus drummondhayi</i>
<i>A. oxyrinchus desotoi</i>	<i>Hypoplectrus gemma</i>
<i>A. o. oxyrinchus</i>	<i>Mycteroperca jordani</i>
<i>A. transmontanus</i>	<i>Mycteroperca prionura</i>
<i>Alosa alabamae</i>	<i>Cynoscion othonopterus</i>
<i>Hypomesus transpacificus</i>	<i>Totoaba macdonaldi</i>
<i>Fundulus jenkinsi</i>	<i>Acanthurus randalli</i>

spawn) or amphidromous (ascending from the sea into freshwater habitats but not for the purpose of spawning). Five species or subspecies of sturgeons are in the diadromous group, followed by five gobies, three smelts, two snooks, one syngnathid, one alosine herring, and the Atlantic salmon. Freshwater habitats in general are more vulnerable to anthropogenic perturbation than most marine habitats, and the preponderance of diadromous species in this list comes as no surprise. The well-documented plight of Pacific coast salmonids provides ample documentation of this fact (Nehlsen et al. 1991). The sturgeons are of particular concern here because they are doubly at risk, having late maturity and long life spans in addition to being subjected to disruption or destruction of spawning and nursery habitats.

Note that we have upgraded five diadromous species listed as *vulnerable* in the recent AFS paper on the status of native freshwater fishes of the southeastern U.S. (Warren et al. 2000) to *threatened* or *endangered*. Of these status changes, those for opossum pipefish (*M. brachyurus*), big-mouth sleeper (*G. dormitor*), river goby (*A. banana*), and slashcheek goby (*C. pseudofasciatus*) were made because of the multiple threats to the ecology of the Indian River Lagoon System recognized herein. In addition, the Atlantic sturgeon was treated in much greater detail in the present paper and analyzed by DPS.

Among other groups that were found to be at risk because of threats to habitat, five syngnathids, one sciaenid, and one goby inhabit sea grass beds which have undergone (and continue to undergo) massive destruction along the southeastern coast of the U.S. Likewise, four species of cyprinodontiform fishes were recognized to be at risk because the mangrove or marsh grass habitats that they require have been destroyed by human development. The vast majority of species recognized to be at risk because of habitat degradation are small in size (< 250 mm TL) (with the obvious exceptions of the sturgeons, Atlantic salmon and a few others). The single most important factor in habitat degradation is mismanagement of freshwater systems that directly affect diadromous species or indirectly affect estuaries or marine ecosystems by altering natural freshwater inflow.

### Geographic "hot spots"

Five geographic areas are identified where several species were at risk. Among these hot spots are three localities in Florida, the Puget Sound and adjacent Canadian waters,

the northern coast of the Gulf of Mexico, and the Gulf of California, especially the northern part.

Florida is the principle locality in the U.S. that harbors tropical marine and estuarine habitats. Therefore, several tropical fish species have their only breeding populations in the U.S. in Florida. The Indian River Lagoon has eight species at risk, including five gobies, two snooks, and one syngnathid. Environmental problems in this unique locality include excessive freshwater influx through activities of the USACE and SFWCD, pollution from toxic chemicals, herbicide spraying, and inlet dredging. Collecting localities within the Indian River Lagoon that previously yielded some of the highest estuarine fish species diversity in the U.S. have been completely destroyed (Gilmore 1995).

The Florida Keys provide coral-reef and mangrove habitats for five species considered to be at risk, all of which are endemic or have their U.S. distribution limited to this small area. These species include three cyprinodontiforms, one small serranid, and a clinid blenny. In addition, several groupers at risk occur there. The Florida Keys

**Table 4.** AFS Status by DPSs. Number of DPSs by species classified as *Endangered (END)*, *Threatened (THR)*, *Vulnerable (VUL)*, or *Conservation Dependent (CD)*.

Species	END	THR	VUL	CD
<i>Rhincodon typus</i>				2
<i>Odontaspis taurus</i>			1	
<i>Cetorhinus maximus</i>			1	1
<i>Carcharodon carcharias</i>				2
<i>Carcharhinus obscurus</i>			2	
<i>Carcharhinus signatus</i>			1	
<i>Pristis pectinata</i>	2			
<i>Pristis perotteti</i>	1			
<i>Amblyraja radiata</i>			1	
<i>Dipturus binoculata</i>			1	
<i>Dipturus laevis</i>			1	
<i>Acipenser brevirostrum</i>	11	2		4
<i>A. medirostris</i>	1	1		
<i>A. o. desotoi</i>	10	4		
<i>A. o. oxyrinchus</i>	16	5		3
<i>A. transmontanus</i>	3	5	1	2
<i>Alosa alabamae</i>			1	
<i>Clupea pallasi</i>			1	
<i>Hypomesus transpacificus</i>		1		
<i>Sprinichus thaleichthys</i>		1	1	
<i>Thaleichthys pacificus</i>		1	1	
<i>Salmo salar</i>	2	2	1	
<i>Gadus macrocephalus</i>			1	
<i>Gadus morhua</i>			3	
<i>Theragra chalcogramma</i>			1	
<i>Merluccius productus</i>			1	
<i>Rivulus marmoratus</i>			1	
<i>Gambusia rhizophorae</i>			1	
<i>Fundulus jenkinsi</i>		1	1	
<i>Menidia conchorum</i>			1	
<i>Anarchopterus criniger</i>			1	
<i>Hippocampus reidi</i>		1		
<i>Hippocampus zosterae</i>			1	
<i>Microphis brachyurus</i>		2		
<i>Syngnathus affinis</i>	1			
<i>Sebastes aulutus</i>			1	
<i>Sebastes auriculatus</i>			1	
<i>Sebastes caurinus</i>			1	
<i>Sebastes crameri</i>			1	
<i>Sebastes entomelas</i>			1	
<i>Sebastes fasciatus</i>				1
<i>Sebastes levis</i>		1		

have undergone extensive development over the last 30 years, and much of the original habitat has been degraded or destroyed. Although some marine protected areas have been established, several more areas, including a diversity of reef, seagrass, and mangrove habitats must be set aside to protect against the loss of these species in U.S. waters.

Florida Bay has six species at risk, including three syngnathids and one sciaenid that occupy seagrass beds in clear water. These species are threatened because of increased turbidity and altered freshwater influx (thus loss of sea grasses) associated with drainage canals from the Everglades to the north (Fourqurean and Robblee 1991; T. Schmidt, NPS data). As with the Indian River Lagoon, more responsible water management is needed in southern Florida if these species are to survive in the U.S. The remaining two Florida Bay species are sawfishes, both *endangered*. Florida Bay and the adjacent Keys appear to be the last remaining refuge in the U.S. for these once widespread, low-productivity species.

Eight species were found to be at risk in Puget Sound. These included four rockfishes, three gadiforms, and one

herring. A unique feature of inner Puget Sound is that its two narrow entrances (Deception Pass and Admiralty Inlet with a sill) appear to partially restrict gene flow between populations in and out of the Sound. The initial declines in the rockfishes and some of the gadiforms appear to have been caused by overfishing species with low productivity. The herring declines were caused by overfishing very localized vulnerable spawning stocks. Most of these stocks have been protected for several years, but recovery is not evident. Several confounding factors appear to be at work. The rockfishes naturally have sporadic and very infrequent recruitment, even when populations are healthy (Parker et al. 2000). Therefore the expectation of successful recruitment of severely depleted stocks of such species is quite low. An apparent environmental regime shift (perhaps associated with global warming) may be occurring and affecting recovery of the Pacific cod at the southern end of its range. In addition, recent years have seen an increase in abundance in harbor seals (*Phoca vitulina*), and a large influx of California sea lions (*Zalophus californianus*), a species seen only occasionally in Puget Sound in the past. High pinniped predation may be preventing recovery of some of these threatened fish stocks. The management challenges to the recovery of fish stocks at risk in Puget Sound appear to be the most complex in North America.

Seven species were found to be at risk along the northern Gulf of Mexico. These include three syngnathids, one anadromous alosine herring, one anadromous sturgeon, and one cyprinodontid. All have become rare or uncommon and are threatened by degradation of essential habitats including sea grass beds, salt marshes, and freshwater spawning and nursery areas (for anadromous species).

Six species of fishes, four of which are endemic to the Gulf of California and adjacent areas, were found to be at risk. These species include four large serranids, and two large sciaenids. All these large species are very sensitive to overharvesting because of late maturity and formation of large localized spawning aggregations. In addition, most, if not all these serranids are protogynous, and the sciaenids require estuarine habitats in the delta of the Colorado River for spawning and nursery grounds. The Colorado River flow has been severely compromised by water removal for agriculture and other uses in the U.S. to the north. This brief review of geographic hot spots is meant solely to flag these areas for much closer scrutiny by the management entities responsible for their administration.

**Degree of risk**

Most (62) DPSs recognized to be at risk in this analysis are listed as *vulnerable*, whereas 35 are *threatened*, 53 are *endangered*, and 16 are *conservation dependent* (Table 4). Of those in the *threatened* or *endangered* categories, 34 are already listed under ESA (Table 5). In this analysis, if a species in its entirety has been listed by a regulatory agency, then all AFS DPSs within the species were assumed to be included in this listing. In addition, 38 are protected by some state regulation or regional FMP (albeit in many cases inadequately), and 45 are on the U.S. Candidate

Table 4. continued.

Species	END	THR	VUL	CD
<i>Sebastes maliger</i>		1		
<i>Sebastes melanops</i>		1		
<i>Sebastes nigrocinctus</i>			1	
<i>Sebastes paucispinis</i>			1	
<i>Sebastes pinniger</i>			1	
<i>Sebastes ruberrimus</i>			1	
<i>Sebastolobus alascanus</i>			1	
<i>Stereolepis gigas</i>		1	1	
<i>Ophiodon elongatus</i>			1	
<i>Centropomus parallelus</i>			1	
<i>Centropomus pectinatus</i>			1	
<i>Dermatolepis inermis</i>			1	
<i>Epinephelus drummondhayi</i>	1			
<i>Epinephelus flavolimbatus</i>	1			
<i>Epinephelus itajara</i>	1			1
<i>Epinephelus nigritus</i>	1		1	
<i>Epinephelus niveatus</i>			1	
<i>Epinephelus striatus</i>		2		
<i>Hypoplectrus gemma</i>			1	
<i>Mycteroperca bonaci</i>			2	
<i>Mycteroperca interstitialis</i>			1	
<i>Mycteroperca jordani</i>			1	
<i>Mycteroperca microlepis</i>			1	
<i>Mycteroperca phenax</i>			1	
<i>Mycteroperca prionura</i>			1	
<i>Mycteroperca xenarcha</i>			2	
<i>Bairdiella batabana</i>			1	
<i>Bairdiella sanctaeluciae</i>			1	
<i>Cynoscion othonopterus</i>			1	
<i>Totoaba macdonaldi</i>	1			
<i>Starksia starcki</i>			1	
<i>Gobiomorus dormitor</i>		1		
<i>Awaous banana</i>		1		
<i>Ctenogobius pseudofasciatus</i>		1		
<i>Eucylogobius newberryi</i>	1			
<i>Gobionellus atripinnis</i>			1	
<i>Gobionellus stigmaturus</i>			1	
<i>Nes longus</i>			1	
<i>Acanthurus randalli</i>			1	
<i>Hippoglossus hippoglossus</i>		1	1	
<b>Totals</b>	<b>53</b>	<b>36</b>	<b>62</b>	<b>16</b>

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Species List. Among the 62 vulnerable DPSs, 14 are on the U.S. Candidate Species List and 9 are protected by state regulations or regional FMPs. It is incumbent upon managers to closely scrutinize the status of all DPSs on this list and to implement conservation measures that not only restore those species most at risk, but to protect those vulnerable DPSs to preclude their listing under the ESA and avoid the often draconian measures necessary to achieve recovery. ➡

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**Table 5.** Official Status by DPSs. Number of AFS DPSs recognized by regulatory agencies: *END* (Endangered), *THR* (Threatened) listings under the ESA. Candidate List (CL) and PRT (Protected), refers to protection through a state or regional management plan whereas *VUL* (Vulnerable) and *SC* (Special Concern) are official listings by COSEWIC, or individual states in the U.S. but do not include legal protection. If an entire species is listed by a regulatory agency it automatically includes all the DPSs for that species identified by AFS.

Species	<i>END</i>	<i>THR</i>	CL	PRT	<i>VUL</i>	<i>SC</i>
<i>Rhincodon typus</i>				1		
<i>Odontaspis taurus</i>			1	1		
<i>Cetorhinus maximus</i>				1		
<i>Carcharodon carcharias</i>				2		
<i>Carcharhinus obscurus</i>			1	1		
<i>Carcharhinus signatus</i>			1	1		
<i>Pristis pectinata</i>			1			
<i>Pristis perotteti</i>			1			
<i>Dipturus laevis</i>			1			
<i>Acipenser brevirostrum</i>	17					1
<i>A. medirostris</i>						1
<i>A. o. desotoi</i>		14				
<i>A. o. oxyrinchus</i>			34	34		1
<i>A. transmontanus</i>	1					1
<i>Alosa alabamae</i>			1			
<i>Clupea pallasii</i>			1			
<i>Hypomesus transpacificus</i>		1				
<i>Spirinchus thaleichthys</i>						1
<i>Thaleichthys pacificus</i>						1
<i>Salmo salar</i>				1		
<i>Gadus macrocephalus</i>			1			
<i>Gadus morhua</i>					1	
<i>Theragra chalcogramma</i>			1			
<i>Merluccius productus</i>			1			
<i>Rivulus marmoratus</i>			1			
<i>Fundulus jenkinsi</i>			1			
<i>Menidia conchorum</i>			1			
<i>Microphis brachyurus</i>			2			
<i>Sebastes auriculatus</i>			1			
<i>Sebastes caurinus</i>			1			
<i>Sebastes maliger</i>			1			
<i>Sebastes paucispinis</i>			1			
<i>Sterolepis gigas</i>				1		
<i>Epinephelus drummondhayi</i>			1			
<i>Epinephelus itajara</i>			1	1		
<i>Epinephelus nigritus</i>			1			
<i>Epinephelus striatus</i>			1	1		
<i>Mycteroperca jordani</i>				1		
<i>Mycteroperca xenarcha</i>				1		
<i>Totoaba macdonaldi</i>	1					
<i>Eucylogobius newberryi</i>	1					
<b>Totals</b>	<b>20</b>	<b>15</b>	<b>58</b>	<b>47</b>	<b>1</b>	<b>6</b>

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