fisheries history

feature

Distribution of Anadromous Fishes in the Upper Klamath River Watershed Prior to Hydropower Dams—A Synthesis of the Historical Evidence

ABSTRACT

Knowledge of the historical distribution of anadromous fish is important to guide management decisions regarding the Klamath River including ongoing restoration and regional recovery of coho salmon (*Oncorhynchus kisutch*). Using various sources, we determined the historical distribution of anadromous fish above Iron Gate Dam. Evidence for the largest, most utilized species, Chinook salmon (*Oncorhynchus tshawytscha*), was available from multiple sources and clearly showed that this species historically migrated upstream into tributaries of Upper Klamath Lake. Available information indicates that the distribution of steelhead (*Oncorhynchus mykiss*) extended to the Klamath Upper Basin as well. Coho salmon and anadromous lamprey (*Lampetra tridentata*) likely were distributed upstream at least to the vicinity of Spencer Creek. A population of anadromous sockeye salmon (*Oncorhynchus nerka*) may have occurred historically above Iron Gate Dam. Green sturgeon (*Acipenser medirostris*), chum salmon (*Oncorhynchus keta*), pink salmon (*Oncorhynchus gorbuscha*), coastal cutthroat trout (*Oncorhynchus clarki clarki*), and eulachon (*Thaleichthys pacificus*) were restricted to the Klamath River well below Iron Gate Dam. This synthesis of available sources regarding the historical extent of these species' upstream distribution provides key information necessary to guide management and habitat restoration efforts.

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Introduction

Gatschet's statement is that salmon ascend the Klamath river twice a year, in June and again in autumn. This is in agreement with my information, that the run comes in the middlefinger month [sic], May–June, and that the large fish run in the fall…They ascend all the rivers leading from Klamath lake (save the Wood river, according to Ball), going as far up the Sprague river as Yainax, but are stopped by the falls below the outlet to Klamath marsh.

—Spier (1930)

Parties coming in from Keno state that the run of salmon in the Klamath River this year is the heaviest it has [sic] ever known. There are millions of the fish below the falls near Keno, and it is said that a man with a gaff could easily land a hundred of the salmon in an hour, in fact they could be caught as fast as a man could pull them in…There is a natural rock dam across the river below Keno, which it [sic] is almost impossible for the fish to get over. In their effort to do so thousands of fine salmon are so bruised and spotted by the rocks that they become worthless. There is no spawning ground until they reach the Upper Lake as the river at this point is very swift and rocky.

—Front page article titled:
"Millions of Salmon—Cannot Reach Lake on Account Rocks (sic) in River at Keno"
Klamath Falls Evening Herald (24 September 1908)

The Klamath River watershed once produced large runs of Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*) and also supported significant runs of other anadromous fish, including coho salmon (*Oncorhynchus kisutch*), green sturgeon (*Acipenser medirostris*), eulachon (*Thaleichthys pacificus*), coastal cutthroat trout (*Oncorhynchus clarki clarki*), and Pacific lamprey (*Lampetra tridentata*). One estimate (Radtke, pers. comm. cited in Gresh et al. 2000) put the historical range of salmon abundance for the Klamath-Trinity River system at 650,000–1 million fish. These runs contributed to substantial commercial, recreational, subsistence, and Tribal harvests (Snyder 1931; Lane and Lane Associates 1981; USDI 1985; USFWS 1991; Gresh et al. 2000). In particular, the Upper Klamath River above Iron Gate Dam once supported the spawning and rearing of large populations of anadromous salmon and steelhead (Lane and Lane Associates 1981; FERC 1990).

The first impassable barrier to anadromous fish on the mainstem Klamath River was Copco 1 Dam, completed in 1918 (followed by Copco 2 Dam in 1925 and Iron Gate Dam in 1962; Figure 1). Prior to dam construction, anadromous fish runs accessed spawning, incubation, and rearing habitat in about 970 km (600 miles) of river and stream channel above the site of Iron Gate Dam. This dam, at river kilometer 307 (river mile 190; Photo 1), is the current limit of upstream passage. The Long Range Plan for the Klamath River Basin Conservation Area Fishery Restoration Program (USFWS 1991) identified the lack of passage beyond Iron Gate Dam as a significant impact to the Klamath River anadromous fishery. At present, significant un-utilized anadromous fish habitat exists upstream of Iron Gate Dam (Fortune et al. 1966; Chapman 1981; NRC 2003; Huntington 2004). The Klamath Hydroelectric Project operating license expires in 2006 and the relicensing process is currently under way.

Need for Information on the Upstream Extent of Anadromous Fish Distribution

Knowledge of the presence and the historical extent of the upstream distribution for anadromous species on the Klamath River is important for restoration planning and future management decision-making. Public Law 99-552, the Klamath River Basin Fishery Resources Restoration Act (Klamath Act), was adopted by Congress on 27 October 1986, for the purpose of authorizing a 20-year federal-state cooperative Klamath River Basin Conservation Area Restoration Program for the rebuilding of the river's fishery resources to optimal levels. Among other charges, the Klamath Act directs the Secretary of Interior to improve and restore Klamath River habitats and promote access to blocked habitats, to rehabilitate problem watersheds, to reduce negative impacts on fish and fish habitats, and to improve upstream and downstream migration by removing obstacles and providing facilities for avoiding obstacles.

In addition to the Klamath Act, the Department of the Interior and the Department of Commerce are authorized to protect and restore anadromous fish and their habitats under several authorities including the Federal Power Act (through the requirement of mandatory fishway prescription under Section 18 of the act). Other authorities include the Endangered Species Act; federal Tribal Trust responsibilities; Pacific Coast Salmon Plan; Magnuson-Stevens Fishery Conservation and Management Act (which incorporates delineation of "essential fish habitat"); Sikes Act, Title II; the Fish and Wildlife Coordination Act; the Wild and Scenic Rivers Act; the National Historic Preservation Act; Federal Lands Protection and Management Act; Northwest Forest Plan; and various policies and initiatives of the U.S. Bureau of Land Management, U.S. Forest Service, the National Park Service, NOAA Fisheries and the U.S. Fish and Wildlife Service (USFWS). The states of Oregon and California also have significant regulatory authorities and responsibilities related to hydropower relicensing and the recovery of listed species.

These authorities provide a basis for restoration of native anadromous fish to their historical habitats. However, there have been persistent questions regarding whether anadromous fish occurred historically above Iron Gate Dam. Thus, prior to implementing anadromous fish restoration and the design of potential fishways that would be species specific, it is important to evaluate the evidence regarding which native anadromous species were present historically above Iron Gate Dam and determine the extent of their upstream distribution.

Methods

We summarize existing information regarding both the recorded historical (tens to thousands of years) presence and, more specifically, the upstream extent of the distribution of native anadromous fish in the Klamath River, based upon photos, historical documents, logical reasoning, and other available information. A distinction was made between presence and the extent of upstream distribution because, for some species, there was clear evidence for presence in general terms, but only vague information on their farthest upstream distribution. When reliable information on the extent of upstream distribution was available, it was important to include this level of certainty for consideration during relicensing and anadromous fish restoration. The presence of species above one dam, but not another, has implications for relicensing.

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Photo 1. Iron Gate Dam has no fish passage facilities.

In this article, references to the Klamath Upper Basin include the Klamath River watershed upstream from and including the section of the Klamath River known as Link River. (Link River Dam, as shown in Figure 1, is on this short reach of the mainstem Klamath River immediately below Upper Klamath Lake).

Photos

We reviewed historical photo collections of the Klamath County Museum and Klamath Historical Society for documentation of anadromous fish above Iron Gate Dam. We assumed that captions on photos correctly identified the taxa, locations, and dates. The photos used here were taken in the vicinity of Klamath Falls and adjacent Link River.

Documents and Reports

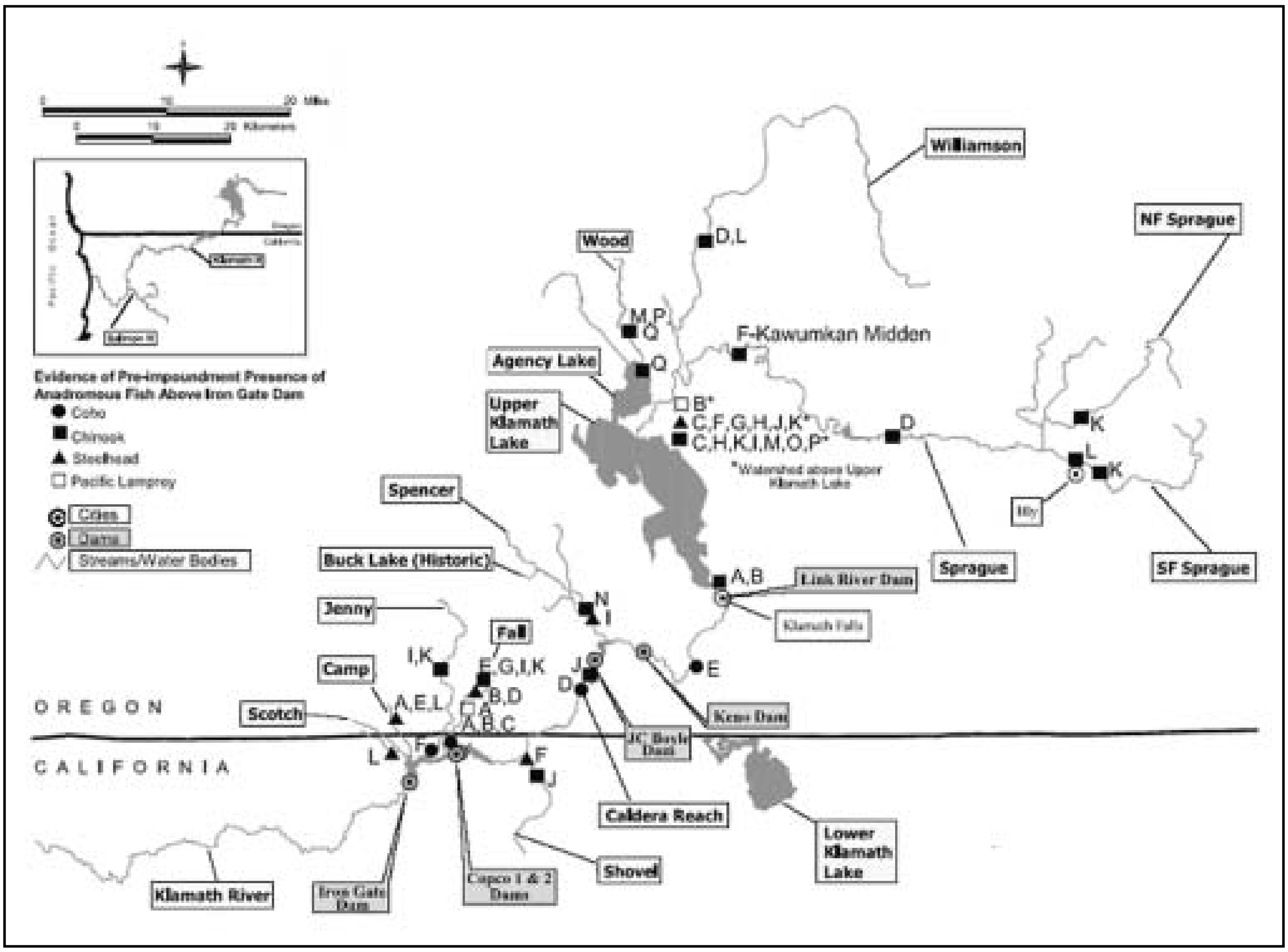
We reviewed published and unpublished fisheries, archeological, and ethnographic reports on the distribution and presence of anadromous fish in the Klamath River watershed. For a given reference we generally cited only the farthest upstream occurrence of a species in the Klamath River and/or its tributaries. When documents identified fish as only salmon, we assumed they were Chinook salmon. While ethnographic (Gatschet 1890; Spier 1930; Kroeber and Barrett 1960) and archaeological (Cressman et al. 1956) sources are cited, other reports from these disciplines may well contain additional documentation not specifically referenced in this paper. Fortune et al. (1966) referenced numerous articles from Klamath Falls newspapers regarding historical accounts of salmon above the current location of Iron Gate Dam. Of these, we have included only one (Klamath Falls Evening Herald 1908).

Personal Communications

We did not reference personal communications that included questionable identifications of species unless the communication included other supporting facts that would corroborate the identification of that species. For example, we discounted the identification of chum salmon (*Oncorhynchus keta*), coho salmon, and steelhead trout in the vicinity of Agency Lake and the Wood River, but included the reference to Chinook salmon because other information communicated on the size of these fish supported that identification.

Personal communications cited in Lane and Lane Associates (1981) regarding the presence of salmon in the Williamson and Sprague rivers were very numerous and we recommend that interested parties refer to this citation. We did not reference these personal communications individually here. When personal communications cited therein provided key information on presence or farthest upstream distribution of a species not cited elsewhere, we referenced Lane and Lane Associates (1981).

Figure 1. Extent of upstream distribution for anadromous fish in the Klamath River and tributaries based upon references in Table 1 (locations for citations are approximate).



Logical Reasoning

For Pacific lamprey and coho salmon we combined existing evidence with logical reasoning for a determination of the extent of upstream distribution of these species in the Klamath River watershed. This reasoning was partly based on the occurrence of the same species east of the Cascade Range in the Columbia River Basin. While we believe this reasoning is valid, we acknowledge that it does not have the same level of certainty as photographs, documents, reports, or personal communications for a specific determination of the limit of upstream distribution.

Results and Discussion

Table 1 summarizes sources of evidence for the historical distribution of Chinook salmon, steelhead, coho salmon, and Pacific lamprey above Iron Gate Dam on the Klamath River. Figure 1 is the corresponding map showing the locations cited for each species.

Evidence for the largest, most utilized species, Chinook salmon, was available from the greatest variety of sources and provided the highest level of certainty. Less information was available for the other three species. Nevertheless, there was substantial information and reasoning to determine that steelhead historically migrated to the Klamath Upper Basin and that the distribution of coho salmon and Pacific lamprey extended above Iron Gate Dam. More detailed information on our evaluation of sources and the presence and farthest upstream distribution is discussed below.

Chinook Salmon

Presence—Information cited here that provides evidence for the presence of Chinook salmon above the current site of Iron Gate Dam includes 2 historical photographs, 14 documents or reports, and 1 personal communication. Numerous other personal communications, testimony, and newspaper articles documenting the presence of Chinook salmon are referenced in Fortune et al. (1966) and Lane and Lane Associates (1981). We found one report that stated there was not enough information to conclude that Chinook salmon accessed tributaries of Upper Klamath Lake.

Chinook salmon spawned in Jenny Creek (Coots 1962; Fortune et al. 1966) and Fall Creek (Wales and Coots 1954; Coots 1957; Coots 1962; Fortune et al. 1966) prior to the construction of Iron Gate Dam. An interview with long-term resident of the area, W. G. Hoover, provided information on large concentrations of fall-run king salmon in Shovel Creek and on spawning that might have occurred near Shovel Creek in the mainstem Klamath River (Coots 1965). Hoover also noted that the river near the "Frame Ranch" was a favorite salmon spearing site and a potential spawning area (Coots 1965). Hoover was undoubtedly referring

Table 1. Documentation for pre-impoundment presence and extent of upstream distribution for anadromous fish in the Klamath River above Iron Gate Dam.

Source	**Species**			
	Chinook (■)	Steelhead (▲)	Coho (●)	Pacific Lamprey (❑)
Photos of historical presence above Iron Gate Dam	(A) Klamath County Historical Society Photo, Photo 2 (1860) (B) Klamath County Historical Society, Photo 3 (1891)			
Documents/reports/ other evidence	(C) *Gatschet (1890)* (D) *Spier (1930)* (E) *Wales and Coots (1954)* (F) *Cressman (1956)* (G) Coots (1957) (H) *Kroeber and Barrett (1960)* (I) Coots (1962) (J) Coots (1965) (K) Fortune et al. (1966) (L) Lane and Lane Associates (1981) (M) *Nehlsen et al. (1991)* (N) BLM et al. (1995) (O) *Thurow et al. (1997)* (P) *Moyle (2002)*	(A) Wright (1954) (B) Coots (1957) (C) *Kroeber and Barrett (1960)* (D) Coots (1962) (E) King et al. (1977) (F) Fortune et al. (1966) (G) Lane and Lane Associates (1981) (H) *Nehlsen et al. (1991)* (I) BLM et al. (1995) (J) *Thurow et al. (1997)* (K) *Moyle (2002)*	(A) Coots (1957) (B) Coots (1962) (C) CDWR (1964) (D) NMFS (1997) (E) IMST (2003)	(A) Coots (1957) (B) *Kroeber and Barrett (1960)*
Personal communications	(Q) Scarber (2004)	(L) Maria (2003)	(F) Bulfinch (2002)	
Logical reasoning			X	X

Italics = published literature. Reference identification letters correspond to symbols (■, ▲, ●, and ❑) showing approximate locations cited for each species (Figure 1).

to the "Frain Ranch" reach of the Klamath River, which is immediately upstream of the Caldera reach (Figure 1). BLM et al. (1995) referred to accounts of fall-run salmon in Spencer Creek and contained a photo taken prior to 1917 showing a Chinook salmon caught at the confluence of Spencer Creek and the Klamath River.

Two historical photographs document the presence of Chinook salmon at Link River. The Klamath County Historical Society provided these photos, dated 1860 and 1891, showing fishermen with their catch of salmon at Link River (Photos 2 and 3; Photo 2 is dated 1860 but may have been taken later in the nineteenth century; Judith Hassen, Klamath County Museum, pers. comm.). Fortune et al. (1966) reported that C. E. Bond, professor of fisheries at Oregon State University, examined a historical photo of salmonids from the Klamath Upper Basin and positively identified at least one fish as a Chinook salmon. We believe this photo may have been Photo 3 because it was available to the author and is the best known photo from the Klamath Upper Basin with a "salmon fishing" caption. The other three fish shown in this photo are clearly salmonids and likely were Chinook salmon as well.

In a footnote, Snyder (1931) referred to interviews he conducted with fishermen and long-time residents of the Klamath Lake region to learn of the past salmon runs. He reported that "testimony was conflicting and the lack of ability on the part of those offering information to distinguish between even trout and salmon was so evident, that no satisfactory opinion could be formed as to whether king salmon ever entered Williamson River and the smaller tributaries of the lake. However, this may be, large numbers of salmon annually passed the point where Copco Dam is now located." No information is provided in Snyder (1931) regarding the number of interviews or the effort made to interview fishermen and long-time residents.

In contrast, we found numerous historical accounts and fisheries reports referring to the presence of salmon in the tributaries to Upper Klamath Lake, in particular, the Williamson and Sprague rivers. Cressman et al. (1956) reported archeological evidence of salmon bones from the Kawumkan midden on the Sprague River (Figure 1), leading him to conclude that salmon passed the falls at the south end of Upper Klamath Lake. Lane and Lane Associates (1981) provided multiple accounts of the presence of anadromous salmonids and fishing in Sprague and Williamson rivers. This report was done under contract for the Bureau of Indian Affairs in the 1980s. Interviews were included in Lane and Lane Associates (1981) to ensure that a record of anadromous fish presence and the fishery on the Tribal reservation in the Klamath Upper Basin was maintained. In excerpts from 50 interviews, conducted in the 1940s, members of the Klamath Tribe and older non-Indian settlers in the region provided accounts of numerous salmon fishing locations on the Sprague River, the Williamson River, Upper Klamath Lake, and Spencer Creek. These accounts made a distinction between salmon and trout. In many instances the interviews in the document provided details on the weights of fish that indicated they could only be Chinook salmon.

One of the earliest references in Lane and Lane Associates (1981) is to the explorer Fremont's visit to the outlet of Upper Klamath Lake in May of 1846 and his observation of great numbers of salmon coming up the river to the lake. Most likely these would have been spring-run Chinook. Kroeber and Barrett (1960) stated that salmon ran up the Klamath into the Klamath lakes and their tributaries. Gatschet (1890) and Thurow et al. (1997) included the Klamath Upper Basin as within the range of Chinook salmon at the time of European settlement. Nehlsen et al. (1991) and Moyle (2002) referred to historical occurrences of fall, spring, and summer races of Chinook salmon in the Sprague, Williamson, and Wood rivers in the Klamath Upper Basin. Their accounts are similar to those of Fortune et al. (1966) and Lane and Lane Associates (1981) for the Sprague and Williamson rivers. For the Wood River, Nehlsen et al. (1991) and Moyle (2002) both state that Chinook salmon historically used this drainage. While one reference states that salmon did not go up the Wood River (cited in Spier 1930), an account of Chinook salmon harvest (Robert Scarber, former Klamath Agency Reservation resident, pers. comm., 2004) provides specific information that Chinook salmon occurred adjacent to and in the Wood River watershed. The Wood River has and continues to have suitable water quality and physical habitat to support anadromous salmonids. Without the presence of fish passage barriers, salmon undoubtedly inhabited this watershed.

Both spring and fall runs were reported above Upper Klamath Lake by Spier (1930) and Coots (1962). Fortune et al. (1966) provided reports and personal interviews that indicated the Sprague River was the most important salmon spawning stream, on the basis of testimony he received. According to four people interviewed by Fortune et al. (1966), salmon entered the Williamson River in autumn, possibly as early as August. One person interviewed provided the observation that, after salmon passed Link River, it took them five or six days to make their way through Klamath Lake before they reached the Williamson.

It is possible that fall-run Chinook reached Upper Klamath Lake and beyond in only wetter years. The lower Klamath River fall run (below Iron Gate Dam) is generally from August to October/November when flows and depths are often lowest for the year (Myers et al. 1998). Successful fish passage through the high gradient Caldera reach for large-bodied, fall-run Chinook may have been problematic during certain years. This low water passage difficulty was noted a short distance upstream at Keno in the Klamath Falls Evening Herald (1908). Spring-run Chinook salmon, on the other hand, have a bi-modal run distribution that spreads from April to August. The smaller sized, spring-run Chinook (their average weight was 5 kg or 11 lbs. according to Snyder 1931) encountered higher spring flows and would have been able to pass the Caldera reach. However, salmon runs to the Klamath Upper Basin undoubtedly had a fall-run component as evidenced by the size of salmon harvested (up to 27 kg or 60 pounds) and the timing of spawning noted in Lane and Lane Associates (1981).

Extent of Upstream Distribution—The extent of upstream distribution we found for Chinook salmon is shown in Figure 1. Chinook salmon utilized habitat in the Sprague River in the vicinity of Bly, Oregon, and further upstream. Fortune et al. (1966) reported that Chinook salmon spawned in the mainstem Sprague River; upstream on the South Fork of the Sprague above Bly to the headwaters; and on the North Fork of the Sprague as well (Figure 1). Lane and Lane Associates (1981) provided several independent testimonies that put the farthest upstream distribution of salmon for the Sprague River in the vicinity of Bly, Oregon. It should be noted that testimonies from Tribal members in Lane and Lane Associates (1981) were oriented toward harvest of adult salmon, which was restricted to within the reservation boundary, also located near Bly. Their report contained little information on the extent of anadromous salmonids in the Sprague River upstream of the reservation boundary. For the Williamson River, both Spier (1930) and Lane and Lane Associates (1981) listed the farthest upstream distribution of salmon as being the falls below the outlet to Klamath Marsh (Figure 1).

We note that accounts of Chinook harvest in general are based upon fisheries that took place in locations convenient for harvest, primarily in mainstem channels, and that the true farthest upstream distribution was probably above the sites where these fisheries took place.

Steelhead

Presence—Information cited here that provides evidence for the presence of steelhead above the current site of Iron Gate Dam includes 11 documents or reports and 1 personal communication. Other personal communications regarding steelhead above Iron Gate Dam are referenced in Lane and Lane Associates (1981). One report stated there was not enough information to conclude that steelhead accessed the Klamath Upper Basin.

BLM et al. (1995) includes a photo captioned "Fishing for steelhead on Spencer Creek…around 1900" from the photo collection of the Anderson Family, descendents of Hiram Spencer, an early settler in the Spencer Creek area. Fortune et al. (1966) cited a brochure from Southern Pacific Railroad, published in 1911, that referred specifically to the harvest of steelhead at the mouth of Shovel Creek (Figure 1).

KLAMATH COUNTY HISTORICAL SOCIETY

Photo 2. Link River salmon "fishing" around 1860. Site of present Klamath Falls.

KLAMATH COUNTY HISTORICAL SOCIETY

Photo 3. Gentlemen display their catch while salmon fishing on the rapids of Link River, 1891.

Extent of Upstream Distribution—The extent of upstream distribution we found for steelhead is shown in Figure 1. California Department of Fish and Game (CDFG) files include records of steelhead spawning in Camp Creek up to 1.6 km (one mile) upstream from the California state line, in at least one Camp Creek tributary approximately 0.8 km (0.5 mile) downstream from the California state line, and in nearby Scotch Creek (Dennis Maria, CDFG, pers. comm.). Wright (1954) and King et al. (1977) also reported that steelhead spawned in Camp Creek prior to the construction of Iron Gate Dam.

Coots (1957, 1962) discussed steelhead in Fall Creek. According to Puckett et al. (1966), steelhead were present as far upstream as Link River, but their presence above Upper Klamath Lake could not be documented. However, Kroeber and Barrett (1960), Nehlsen et al. (1991), Lane and Lane Associates (1981), Thurow et al. (1997), and Moyle (2002) all refer to steelhead accessing the Klamath Upper Basin. Fortune et al. (1966) states that due to the difficulty in differentiating steelhead from large rainbow trout (or redband trout, *Oncorhynchus mykiss irideus*), accurate information on the history of steelhead migrations in the Klamath Upper Basin was impossible to obtain. However, Fortune et al. (1966) also stated that there was enough agreement from interviews conducted to derive some general information. Included in this general information were accounts of steelhead in the Wood, Sprague, and Williamson rivers.

Generally, in watersheds where both Chinook salmon and steelhead are present, the range of steelhead is the same if not greater. The reports above, the overlapping distribution for the two species in most watersheds, and the fact that Chinook salmon were present in the Klamath Upper Basin are substantial evidence that steelhead were also present in tributaries to Upper Klamath Lake.

Coho Salmon

Presence—Information cited here that provides evidence for the presence of coho salmon above the current site of Iron Gate Dam includes five documents or reports and one personal communication. Snyder (1931) stated that "[s]ilver salmon are said to migrate to the headwaters of the Klamath to spawn. Nothing definite was learned about them from this inquiry because most people are unable to distinguish them." At the time, he said there was little interest in coho because Chinook salmon were so much larger and more abundant. Fortune et al. (1966) did not discuss coho salmon. However, Coots (1957, 1962) and the California Department of Water Resources (1964) reported that coho salmon spawned in Fall Creek, which now flows into Iron Gate Reservoir. Prior to construction of Iron Gate Dam, the confluence of Jenny Creek with the main stem Klamath River was well known by fishing guides as one of the best places in the upper river to fish for coho (Table 1 and Figure 1; Kent Bulfinch, Klamath River Basin Task Force representative, pers. comm.).

In 1911, 881 female coho were captured at the Klamathon Racks egg-taking facility about 8 km downstream from the current Iron Gate Dam site (CDFG 2002). Coho salmon are generally tributary spawners, and the only sizable tributary between the Klamathon Racks area and Iron Gate Dam is Bogus Creek. It is unlikely that all these spawning fish would have been destined for Bogus Creek and probable that a significant portion of the return was destined for tributaries above the current site of Iron Gate Dam. NOAA Fisheries estimated that within the Klamath River Basin, the construction of Iron Gate Dam blocked access to approximately 48 km (30 miles) of mainstem habitat, about 8% of the historical coho salmon habitat in the entire Klamath River Basin (NMFS 1997).

Extent of Upstream Distribution—The NOAA Fisheries estimate of the loss of approximately 48 km (30 miles) of mainstem coho salmon habitat above Iron Gate Dam would put the species' upper distribution in the vicinity of the J. C. Boyle powerhouse (Table 1 and Figure 1; NMFS 1997). Another report put the historical occurrence of coho salmon in the Klamath River as far upstream as the mouth of Lower Klamath Lake (IMST 2003). However, the report by Moyle (2002) stating that coho salmon once ascended the Klamath River and its tributaries at least as far upstream as Klamath Falls, Oregon, is an error resulting from the author's imprecise use of zoogeographic boundaries (Peter Moyle, University of California Davis, pers. comm.). To the best of his knowledge, there are no records of coho in the Klamath Upper Basin.

Given this information about the distribution of coho salmon in the mainstem Klamath River, the fact that coho are generally tributary spawners, our knowledge of their rearing and spawning habitat, and the characteristics of various Klamath River tributaries, we conclude that coho salmon would have used Spencer Creek, a medium-sized, low-gradient tributary, with suitable spawning habitat. Side channel and beaver pond areas in Spencer Creek would also have provided rearing habitat for this species. Thus, we reason that the farthest upstream distribution of coho salmon likely extended at least to this vicinity.

Anadromous Pacific Lamprey

Presence—We found two documents, but no personal communications, that provided evidence for the presence of Pacific lamprey above the current site of Iron Gate Dam. Coots (1957) reported that *Lampetra tridentata* entered Fall Creek, which now flows into Iron Gate Reservoir. Literature references to Pacific lamprey in the Klamath Upper Basin prior to the construction of downstream dams (Gilbert 1898; Evermann and Meek 1897) may have applied to a resident, non-anadromous taxon of uncertain systematic status (Stewart Reid, USFWS, pers. comm. 2004). Gilbert (1898) reported a "young" specimen that measured 26 cm in length. Lampreys of this size correspond with the larger lamprey taxon still encountered in Upper Klamath Lake, but are considerably smaller than anadromous adults in the Klamath River (Kan 1975; Lorion et al. 2000). The current lamprey taxon in Upper Klamath Lake was recognized as a distinct subspecies of *L. tridentata* by Kan (1975) in his unpublished dissertation, and as "non-anadromous" *L. tridentata* in Lorion et al. (2000) due to the lack of a formal systematic revision of the Klamath lampreys. Mitochondrial DNA analysis has shown no evidence of contemporary anadromous Pacific lamprey populations in the Klamath Upper Basin or Spencer Creek (Lorion et al. 2000; Margaret Docker, Great Lakes Institute for Environmental Research, pers. comm. 2004).

This taxonomic confusion would have made it difficult to distinguish anadromous Pacific lamprey from resident taxa. However, anadromous Pacific lamprey currently occur throughout the mainstem and principal tributaries of the lower Klamath River and fish fauna are generally considered to be similar throughout the mainstem Klamath River upstream to Spencer Creek. Historically, there were no physical barriers that would have prevented anadromous lampreys from migrating above Iron Gate Dam (Stewart Reid, USFWS, pers. comm.).

Extent of Upstream Distribution—Kroeber and Barrett (1960) reported that Pacific lamprey ascended to the Klamath Lakes, based on the accounts of Native Americans (Table 1, Figure 1). While the difficulty in distinguishing anadromous Pacific lamprey from Klamath Upper Basin resident lamprey taxa brings this account into question, we note that the historical distribution of Pacific lamprey in the Columbia and Snake rivers was coincident wherever salmon occurred (Simpson and Wallace 1978). Wydoski and Whitney (2003) stated that Pacific lampreys occur long distances inland in the Columbia and Yakima river systems. Pacific lamprey still migrate well upstream to at least the Snake River (Christopher Claire, Idaho Department of Fish and Game, pers. comm.) and Idaho's Clearwater River drainage (Cochnauer and Claire 2002). Current limits to the distribution of Pacific lampreys in the Columbia River system are at Chief Joseph Dam on the mainstem Columbia and Hells Canyon Dam on the Snake River (Close et al. 1995). Both of these dams are well over 800 km (500 miles) upstream from the ocean and Pacific lamprey distribution may have extended further upstream prior to the construction of these dams, which have no fish passage facilities. On the Willamette River, Pacific lamprey were historically able to pass upstream at Willamette Falls with winter steelhead and Chinook salmon (USDI 2003).

The extent of Pacific lamprey migrations in other coastal rivers, their general congruence with anadromous salmonid distributions, the historical absence of lamprey passage barriers in the mainstem Klamath River, and the homogeneity of the lower Klamath River fish fauna throughout the mainstem Klamath upstream to Spencer Creek suggest that, historically, anadromous Pacific lamprey would likely have migrated up the Klamath River past where Iron Gate Dam now exists and that their upstream distribution extended to at least Spencer Creek.

Other Anadromous Species

Sockeye Salmon— There is some evidence that a run of sockeye salmon may have occurred in the Klamath River above the current location of Iron Gate Dam. The southernmost distribution of sockeye (*Oncorhynchus nerka*) in North America is recorded as the Klamath River (Jordan and Evermann 1896; Scott and Crossman 1973). Cobb (1930) reported that 20 sockeye were taken in the Klamath River in the autumn of 1915. Sockeye salmon require a lake for rearing. The only potential lake rearing habitat in the Klamath River system accessible to anadromous fish would have been Upper Klamath Lake, Lower Klamath Lake, or Buck Lake (in the upper reaches of Spencer Creek before being drained, Figure 1). Lower Klamath Lake was probably too shallow to provide suitable rearing habitat for sockeye salmon, but some authors (Fry 1973; Behnke 1987) believe that a small run of sockeye may have occurred to Upper Klamath Lake, until eliminated by dams. However, Snyder (1931) reported that no evidence substantiated the statement of Jordan and Evermann (1896) that sockeye salmon occur in the Klamath River, and Moyle (2002) stated that individual anadromous sockeye found in streams south of the Columbia system are probably non-spawning strays or kokanee (the landlocked form of sockeye) that went out to sea. At any rate, if anadromous sockeye were present historically, they have been extirpated.

It is notable that kokanee salmon currently are observed in Upper Klamath Lake (Logan and Markle 1993), especially in springs on the west side of the lake (Bill Tinniswood, ODFW, pers. comm.). These are believed to be fish that have drifted downstream from the Four Mile Lake population, introduced in the 1950s or before (Bill Tinniswood, ODFW, pers. comm.; Roger Smith, ODFW, pers. comm.).

Green Sturgeon—To the best of our knowledge there is no evidence for the distribution of native sturgeon above the current location of Iron Gate Dam. Chuck Tracy (ODFW, pers. comm.) stated that the upstream limit of distribution appears to be Ishi-Pishi Falls (near the confluence of the Klamath River and the Salmon River) on the Klamath River. Moyle (2002) mentioned a green sturgeon spawning site in the Klamath River approximately

208 km (129 miles) below Iron Gate Dam. Sturgeon are known to spawn in the Salmon River, a tributary to the lower Klamath River, which flows into the Klamath River about 201 km (124 miles) below Iron Gate Dam. Kroeber and Barrett (1960) put the upstream-most distribution of sturgeon in the same vicinity. While some green sturgeon may presently migrate beyond the confluence of the Salmon and Klamath rivers, they are the exception rather than the rule (Tom Shaw, USFWS, pers. comm.).

Gilbert (1898) reported that green sturgeon were not observed in Upper Klamath Lake. The current small population of sturgeon in Upper Klamath Lake is derived from white sturgeon (*Acipenser transmontanus*) introduced in 1956 (ODFW 1997).

Eulachon—To the best of our knowledge there is no evidence of the distribution of eulachon above the current location of Iron Gate Dam. Eulachon are usually restricted to spawning in lower river reaches (Scott and Crossman 1973). Accounts of Yurok Tribal elders indicate that eulachon utilized the lower Klamath River for spawning at least as far upstream as 40 km (river mile 25; Larson and Belchik 1998). Historically abundant, they may now be extirpated in the Klamath River (Larson and Belchik 1998).

Cutthroat Trout—Typically, coastal cutthroat do not occur more than about 160 km (100 miles) from the coast (Behnke 1992). There are no accounts of cutthroat in the Klamath Upper Basin. Considering the multiple life history strategies cutthroat exhibit, had they been present above Iron Gate Dam historically, there would likely be resident populations in the upper basin or other tributaries above the dam.

Chum Salmon—To the best of our knowledge there is no evidence for the distribution of chum salmon, above the current location of Iron Gate Dam. The distribution of chum salmon is generally limited to lower river reaches (Scott and Crossman 1973). Small runs of this species still maintain themselves in the lower Klamath River (Moyle 2002).

In some historical accounts there are references to dog salmon in the Upper Klamath River Basin. Dog salmon is a common reference used for chum salmon in the Pacific Northwest and Alaska. However, the common name dog salmon was also applied to Chinook salmon in the Klamath River in early accounts (Snyder 1931; Lane and Lane Associates 1981). Hence, there may have been confusion as to the upstream distribution of chum salmon in the Klamath River.

Pink Salmon—To the best of our knowledge there is no evidence for the distribution of pink salmon (*Onchorynchus gorbuscha*) above the current location of Iron Gate Dam. The distribution of pink salmon is generally limited to lower river reaches (Scott and Crossman 1973). Small numbers of pink salmon have been reported in the lower Klamath River (Moyle 2002).

Conclusions

We found numerous sources of information regarding the occurrence of Chinook salmon, steelhead, coho salmon, and Pacific lamprey above the current location of Iron Gate Dam on the Klamath River. We are not aware of any credible reports that these species did not migrate beyond this point. For Chinook salmon and steelhead, we found one report for each species stating there was not enough information to say definitively they migrated into the Klamath Upper Basin. In contrast, we found several lines of evidence that clearly showed that Chinook salmon historically migrated to the Klamath Upper Basin. A determination of the upstream extent of distribution for steelhead, coho salmon, and Pacific lamprey was more difficult. However, available documentation indicates that steelhead accessed habitat in the tributaries of Upper Klamath Lake as well. Pacific lamprey probably accessed habitat upstream at least to Spencer Creek and possibly beyond, as did coho salmon. There is limited evidence that a small run of sockeye salmon may have accessed habitat in Upper Klamath Lake or Buck Lake. Green sturgeon distribution extended upstream to the vicinity of the Salmon River in the mid-Klamath River portion of the watershed. Chum salmon, pink salmon, eulachon, and cutthroat trout were limited to the lower Klamath River, well below the current location of Iron Gate Dam. This documentation resolves a great deal of the uncertainty regarding which species were present above Iron Gate Dam and the extent of their upstream distribution, both key to realizing fisheries restoration opportunities.

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education feature

Infusing Constructivist Learning in Fisheries Education

ABSTRACT

Academics increasingly advocate constructivist learning, which encourages student control of their learning. Constructivist approaches were used in four of six offerings of an introductory fisheries and wildlife class at Michigan State University from 2001–2004 involving 292 students. Student choices, student grades, and student evaluations were used to evaluate teaching effectiveness. Student ratings of the course dipped during the first semester of constructivist learning implementation. They returned to pre-implementation levels for most categories, and improved for other categories. The average percentage of students exceeding grades of 3.5/4.0 increased from 12% to 21% in the semesters after full implementation. Adopting a constructivist approach led to improved grades and good student-instructor interaction. Constructivist learning creatively empowered students, but exceeded student expectations for responsibility and self direction. Embrace of the constructivist approach requires persistence, flexibility, care, and monitoring.

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Review of Pedagogy

Proponents of the learning paradigm seek to shift the emphasis from teaching and instructors to learning and learners (Barr and Tagg 1995; Campbell and Smith 1997). Student-centered active learning exemplifies the paradigm shift (Meyers and Jones 1993; Johnson et al. 1998; Thompson et al. 2003). Active learning turns the focus from a teacher providing information to passive students, toward students participating in knowledge acquisition through various means. Active learning includes approaches such as cooperative learning (Smith and Waller 1997; Johnson et al. 1998), problem-based learning (Duch 1995; Lieux 1996), experiential learning (Kolb 1984), and case-based learning (Habron and Dann 2003). A continuum exists within the learning paradigm with respect to level of student input and decision making.

Regardless of the approach, active learning requires the teacher to shift from serving as the center of attention and reduces the teacher's dependence upon lecture (Orth 1995; Bull and Clausen 2000; Orth 2000). However, such active learning processes may not fully integrate student-centered learning, which involves altering learning environments to address different learning styles (Guy and Denson-Guy 1995, 1998) or multiple intelligences (Gardner 1999) within a classroom. Proponents of constructivism (Marlowe and Page 1998; Gagnon and Collay 2001; Maypole and Davies 2001) and democratic classrooms (Patrick 1998; Maypole and Davies 2001; Weasmer and Woods 2001) advocate for greater student roles in deciding course content and process within educational settings. In these situations students might exercise varying levels of control over determining reading lists, the number and dates of exams, guest speakers, topics to discuss, as well as assessment methods.

Constructivist learning represents the high end of the student involvement continuum and occurs when learners build their own ways of gaining knowledge "by investigating and discovering for themselves by creating and re-creating, and by interacting with the environment" (Marlowe and Page 1998:16), while incorporating previous experiences. Such learning involves both intra-personal and inter-personal development. Instructors guide learning opportunities instead of serving as the knowledge source. Constructivism owes its development to the work by a wide range of thinkers such as Jerome Bruner, John Dewey, Paulo Freire, Jean Piaget, and Lev Vygotsky among others (Marlowe and Page 1998; Gagnon and Collay 2001).

While many approaches to achieve constructivist learning exist from children to adults, Gagnon and Collay (2001) propose six components to help visualize and implement constructivist learning design: situation, groupings, bridge, questions, exhibit, and reflections.

- Participants first discuss the goals, purpose, and agenda of the learning situation.
- Students form groupings in which to engage the material.
- A bridging activity enables students to identify and link their prior knowledge with the new material.
- Questions then emerge from both students and instructor that help guide the activity.
- Exhibits provide the outputs that students use to demonstrate their learning.
- Then students and instructor reflect upon the activity in terms of both the content and process of learning.

Empirical studies demonstrate that the process of actively questioning, interpreting, problem solving, and creating produces more critical, deeper, and lasting learning than traditional teacher-dominated classrooms (Marlowe and Page 1998).

Constructivist principles not only provide more long-lasting learning, but lead to the critical thinking, analytical, and problem-solving skills required for ecosystem management (Orth 1995; Thompson et al. 2003). Ecosystem management embraces the uncertainty and flexibility of adaptive management, where multiple solutions exist in a dynamic environment. Constructivist approaches do not necessarily compromise the required core content (Marlowe and Page

1998) needed in outcomes-based resource management classes (Zundel and Needham 2000; Zundel et al. 2000) or curriculum (Newcomb et al. 2002; Thompson et al. 2003). So the research question emerged, "How do I incorporate learner-centered, self-directed, emergent learning into an outcomes-based required core course?" In this article, I describe a three-year experience of applying active, constructivist, and democratic learning principles in an introductory fisheries and wildlife course at Michigan State University (MSU).

Academic Context

Introduction to Fisheries and Wildlife (FW100) serves as the entry-level required course for fisheries and wildlife majors at MSU. Enrollment is capped at 25 students per laboratory session leading to a maximum enrollment of 75 in the fall and 50 in the spring. The course strives to achieve learning outcomes in the following areas: principles of fisheries and wildlife, careers, skills, and professional development (Table 1). Students use active learning components such as case studies, direct interaction with resource professionals as guest speakers, field observation projects, problem-solving simulations, and field-based laboratories (Habron and Dann 2003). Major assessment activities included a field observation project with field journal and abstract (30% of course grade), cover letter and resume (5%), a campus orientation exercise (5%), class participation (15%), three exams (30%), and a final exam (15%).

Table 1. The four outcome areas for which students must demonstrate proficiency.

Principles
- definition of fisheries and wildlife management
- management cycle
- scientific method
- habitat
- populations
- human dimensions

Skills
- Critical thinking
- Problem solving
- Map reading
- Compass use
- Observation
- Information collection

Careers
- Job search strategies
- Job titles/occupations
- Agencies and organizations

Professional Development
- Communication
- Networking
- Curricular electives

Methods

Instructional Changes

I began changing the course incrementally as a result of student feedback. Each semester, students completed course evaluations after four weeks of instruction. They expressed a lack of substantive learning, uncertainty of course objectives, a strong interest in experiential learning and real-world experiences, enjoyment of guest speakers, and a desire for hands-on outside learning experiences (Habron and Dann 2003). These data led me to believe that maintaining interest and learning across different interest levels and majors presented a challenge. I hypothesized that incorporating learner-centered approaches would recapture the wonder of natural resources that brings students to the discipline and lead to more positive student evaluations, greater interaction, and improved grades.

Beginning in fall 2001, I began to insert small constructivist and democratic learning components. Every exam contained the same final question that asked students to describe anything they had learned that the exam failed to cover. Students had to identify how they learned about the topic and how the topic related to fisheries and wildlife management. Further, students who registered for the fall 2001 class received an e-mail at the end of spring 2001 enrollment asking them to choose three of six possible case study topics to utilize that fall. That allowed them to influence the case study topics I chose for their semester, while allowing me to prepare the materials over the summer. For the spring 2002 semester, students conducted a group project that required them to contact a guest speaker, generate questions for the speaker to address, collect three references related to the guest speaker topic, and post the references on the class website.

In the fall of 2002, I incorporated the largest shift towards constructivist democratic principles. Aldo Leopold's collection of essays, *The Sand County Almanac*, emerged as the required reading based on low student ratings of two different textbooks. The semester schedule began with only a few guest speakers, while students generated learning interests and identified potential guest speakers. The schedule only showed confirmed topics for 8 of the 15 weeks in the semester. The remaining speakers and topics depended on student interest.

The syllabus contained a list of key concepts and terms under each of the four outcome areas (Table 1). Students could pursue any topic, issue, or guest speaker, but ultimately they had to demonstrate proficiency in understanding the stated outcomes. "Bloom's Taxonomy" (Faculty Institutes for Reforming Science Teaching 2004) served as a guide for students to see how they needed to progress from basic understanding to application, creation, and evaluation for each concept within each of the outcomes (Table 2).

In the first week of class, students responded to a series of questions about their learning rationale. These questions addressed their background in natural resources, motivation for a fisheries and wildlife career, previous learning experiences, and desired learning interests. Responding to the series of questions enabled students to reflect upon their previous knowledge and experiences and develop a learning plan based on those experiences as well as their emerging interests. In addition to generating ideas for guest speakers, the learning rationale provided topics for me to use to select articles, videos, and other learning materials that addressed the required outcomes covered in the first half of the class. Instead of providing students with a case study, each student developed a case study based on individual interests. I asked students to develop their own case studies based on a suggestion from a peer reviewer of a previous article describing case-based learning (Habron and Dann 2003). One case study on tribal fishing remained for the class as a whole to address. A second case study comprised a four-lab sequence focusing on the Red Cedar River that flows through campus.

As in previous semesters, students developed their own question-driven field observation project; however, the weighting of the assignment declined from 30% of the overall grade to 15%. Students earned the remaining 15% through development of an individual portfolio. Portfolios provide an opportunity for students to collect and display visible evidence or exhibits of their learning (Gagnon and Collay 2001). The portfolio assignment contains sections related to individual student interests, individual case study, field project, campus environment, and campus resources. My rationale was to develop an individualized approach within a uniform format enabling each student to demonstrate understanding of the course outcomes through a personally meaningful experience (Fear et al. 2003). The portfolios contain both working and presentation drafts of student work such as abstracts, the case study and resumes, as well as student reflections that offer insights on their emerging knowledge (Gagnon and Collay 2001). The portfolio replaced the previous campus orientation activity that students disliked, but addressed the same learning outcomes.

In 2003–2004, I offered students an option to vary the weighting of any two of their assignments by 5% upon seeing the results of only the first exam. The option encouraged student assessment of learning interests, learning styles, and academic strengths. This choice enabled students to reduce the weight of their first exam from 10% to 5% and increase their portfolio weight from 15% to 20%. Alternatively, students could increase their field project from 15% to 20%, and reduce their portfolio from 15% to 10%.

Data Collection

Data to assess student responses to the approach emerged from several sources. Michigan State University administers end-of-term student evaluation instruments called Student Instructional Rating System reports (SIRS). Students rate each course based on five domains: instructor involvement, student-instructor interaction, student interest, course demands, and course organization. Students rate a total of 21 items using a likert-scale from 1 to 5 with higher scores indicating higher satisfaction. I used analysis of variance (ANOVA) to compare the mean overall score across semesters to assess student responses to differences in pedagogy. I also looked at the mean rank (1–6) of each of the 21 items across the six semesters such that higher mean values resulted in lower ranks across semesters. Levene's test determined that the data met the assumption of homogeneous variances.

Final grades provided one measure of overall student understanding. Students also provide in-semester feedback using instructor-generated evaluation forms, as well as through in-class and online reflective writing assignments. Further, students provided voluntary consent to utilize selected assignments as approved by the MSU University Committee on Research Involving Human Subjects from 2000–2002 and 2003–2004. The approval lapsed for the 2002–2003 school year. Student choices on guest speakers and assignment weighting contributed to the evaluation data. My reflections as the instructor comprise the final piece to interpret student data in the context of each semesters activities. Reflection offers both learners and teachers the ability to assess their individual and collective learning and to iteratively craft new learning strategies based on existing and desired knowledge (Gagnon and Collay 2001). The process of reflection-in-action contributes to knowing-in-action that serves as a hallmark of a scholar-practitioner (Schon 1983).

Results

Student Choices

Prior to adopting a constructivist approach, I chose the same topics or types of speakers to appear each semester. In contrast, students chose a different variety of topics and guest speakers each semester. These selections mirrored the selections I made prior to soliciting input, because I often chose the same speakers since they reflected student interests. Graduate students comprised the greatest percentage of speakers in Fall 2002.

Regarding reallocating the weight of assignments by 5%, 19/42 (45%) students reallocated their assignments in fall 2003. In spring 2004, 5/19 (26%) students exercised that option. Students most frequently adjusted the weight of exam 1, the final exam, and the field project.

Student Evaluation

Analysis of variance of both mean overall scores as well as semester ranks revealed that overall course ratings reached their lowest point during the first semester the full constructivist changes occurred in fall 2002. The mean evaluation scores in the three subsequent semesters reached significantly higher rat-

Table 2. Example of using Bloom's Taxonomy to ask increasingly complex questions as the semester progresses to gauge student proficiency in understanding the definition of fisheries and wildlife concept within the principles outcome area.

Knowledge:	What is the definition of fisheries and wildlife management? (Exam 1)
Comprehension:	Explain the meaning of fisheries and wildlife in your own words? (In class assignment)
Application:	Illustrate the definition using a topic you find interesting. (Case study homework)
Analysis:	Use a diagram to illustrate the three main components of the definition and compare the relative importance of each of the three main components. (Exam 3)
Synthesis:	Use the definition of fisheries and wildlife management to propose a plan to address a topic of interest. (Tribal fishing case study)
Evaluation:	Use the definition of fisheries and wildlife as a guideline to rate the management described in the article we read about this topic. (Final exam)

ings than the scores during fall 2002 (F = 9.299; P<0.000; LSD; Table 3). However, mean scores after fall 2002 did not differ from scores prior to fall 2002. Analysis of the ranked data reveal that fall 2002 scores represent the lowest scores of all six semesters (F = 44.723; P<0.000; LSD; Table 4); and that scores in the three most recent semesters ranked significantly better than prior to the adoption of constructivist approaches.

Student Grades

Grade distributions illustrate that in the two semesters after course changes, on average over 50% of students earned at least a 3.5/4.0 course grade; whereas before the changes, the median course grade did not exceed 3.0 (Figure 1). The average percentage of students exceeding grades of 4.0 increased from 12% to 21% during the semesters after full implementation.

Discussion

Student ratings of the class declined during the fall 2002 semester of implementation. One cannot dismiss the possibility that a uniquely disgruntled set of students participated in fall 2002. However, given the magnitude of the class changes, it is less likely that a distinct class composition explains all of the differences. Despite the change in pedagogy and design, student ratings in the three semesters following full implementation did not decrease from pre-implementation, but grades did improve. Therefore, my experience suggests that if done properly you may implement strong changes toward constructivist, democratic, and active learning without impacting student attitudes or comprehension (Bull and Clausen 2000).

I attribute the dissonance that appeared in the implementing semester to the "armed and dangerous" syndrome that illustrates the "peril of banking on achieving too much too soon" (Marlowe and Page 1998:1) when implementing constructivist classrooms. However, the peril lies not only with the activities themselves, because the activities have not changed in the three semesters since implementation. The danger lurks from my own underestimation of the challenges that the changes presented to students. Students' previous and ongoing experience with education presents them with teacher-directed learning as the norm. I lacked preparation for the anguish and confusion that the students experienced that first semester in fall 2002.

Students failed to comprehend that not only did they have control of the course direction, but that they also needed initiative to take responsibility. Though I believed that providing them control represented my strong interest in their learning, the student evaluations in fall 2002 indicated that students felt less interest from me in their learning than any other FW100 class. They expressed frustration because they did not know when to start or maintain their portfolio activities. Students stated that instructions were vague. Students in other university settings also demonstrated difficulty in following instructions (Smith and Hallmark 2004). My students received feedback, but no grades on preliminary assignments. Most had no experience with portfolios. Some exercised too little effort, while others enacted efforts that far exceeded the needs of the assignment.

Class Adjustments

I attribute the improvement of student ratings and grades after the fall 2002 implementation to changes by the instructor. In fall 2002, the students did not fail, the pedagogy did not fail, but the instructor failed. Linking theory with practice provides a challenge. I cannot overestimate the importance of creating safe and trusting learning spaces (Gagnon and Collay 2001). Creating such spaces requires constant observation, monitoring, reflection, and persistence (Marlowe and Page 1998). Instead of creating such a supportive atmosphere, that first semester of implementation most certainly generated a sense of impending doom for both the students and me, as has occurred elsewhere (Grace 1999).

My experience supports the suggestion that implementing active learning often requires instructors to adjust tactics and provide more student support

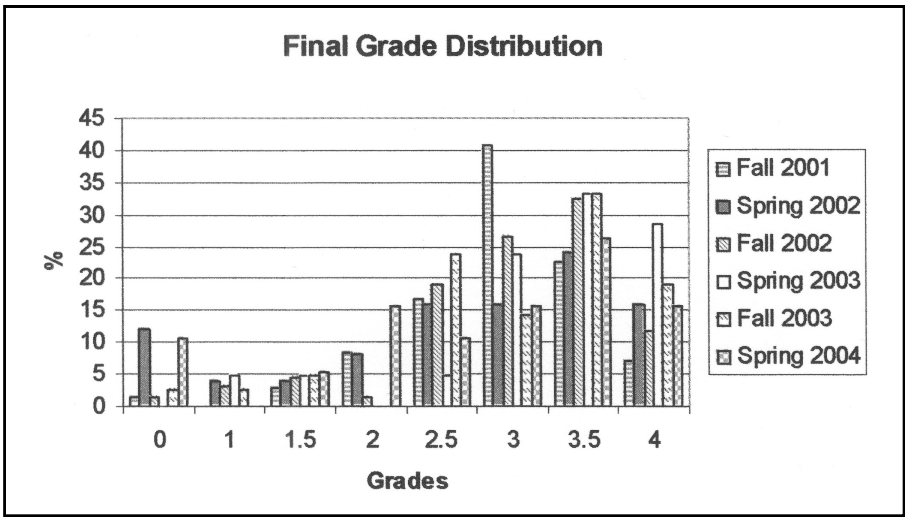
Table 3. Results of analysis of variance for mean student rating (1–5) with high values indicating positive ratings. Means that share letters in superscript do not significantly differ.

Semester	Mean student rating	Standard error	*F*	Significance
Fall 2001	3.82[a,b]	.09173	9.299	*P*<.000
Spring 2002	3.65[b]	.08067		
Fall 2002	3.36[c]	.10025		
Spring 2003	3.99[a]	.08221		
Fall 2003	3.99[a]	.07196		
Spring 2004	4.01[a]	.07951		

Table 4. Results of analysis of variance for student rating ranks (1–6) with low ranks indicating positive ratings. Semesters that share letters in superscript do not significantly differ.

Semester	Mean rank of student rating	Standard error	*F*	Significance
Fall 2001	3.8333[a]	.23231	44.723	*P*<.000
Spring 2002	4.7619[b]	.23558		
Fall 2002	5.6905[c]	.17070		
Spring 2003	2.2619[d]	.25962		
Fall 2003	2.2381[d]	.20592		
Spring 2004	2.2143[d]	.23292		

Figure 1. Percent frequency distribution of final course grades by semester. Grades are on a four-point scale.



(Lieux 1996; Marlowe and Page 1998; Bull and Clausen 2000). Communication must continually occur that lets students know that we understand their awkwardness and stress, and that some efforts are going to fail (Grace 1999). Developing both teacher and student skills regarding reflection also provides guidance (Marlowe and Page 1998; Gagnon and Collay 2001). For example, the first semester of portfolios did not include an opportunity for students to reflect upon their achievements and struggles. For some, the portfolio consisted of a loose collection of artifacts disconnected from the course outcomes or from a student's sense of self. Subsequently, students now use a handout describing key characteristics of reflective writing and practice writing small reflection statements throughout the semester. They share short in-class reflections about their excitement, progress, and concerns regarding the portfolio before the portfolio due date. Students conclude their portfolio with one-page reflection statements that seek to describe their learning journey.

The first week of class now involves in-depth discussions of the philosophy and activities required for the class. Students view all the assignments and criteria and see portfolios that previous students agreed to share. I provide these portfolios during every lab period for student access. Students must address initial portions of their portfolio as weekly homework assignments completed online. An entire mid-semester lab period provides an opportunity for students to share their portfolio progress and to ask clarifying questions. Importantly, while the students experience this approach for the first time each semester, I now have gained the experience to actively look for student tension. I know I need to actively communicate each class period about student progress and remind them of upcoming deadlines.

Utilizing a student-centered approach requires more flexibility and ability to quickly respond by an instructor. In the previous model, I contacted guest speakers months in advance to establish dates that fit busy schedules, but also to arrange speakers in logical sequences. With the current model, students may not identify guest speakers until the second or third week of class. As a result, scheduling preferred speakers becomes more difficult and arranging logical sequences almost impossible. However, a large pool of potential, experienced speakers exists, and some topics such as law enforcement appear every semester. Some students actually prefer peer rather than faculty introduction of guest speakers (Smith and Hallmark 2004).

Conclusion

Advocating a shift toward more student control of course content and format will concern some educators. While I did discontinue a course textbook and the campus orientation exercise, I did not abandon the outcomes upon which they were based. Focusing on an outcomes-based approach enables students and instructors the freedom to create the most appropriate learning environment possible without sacrificing content. I imagine such an approach can work in advanced classes with core content such as ichthyology, physiology, geographic information systems, or fishery management as well. In such cases, students could determine how, when, where, and with whom they learn to distinguish among fish species such as darters or sunfish. While some students might prefer traditional hands-on labs, others might choose to visit online taxonomic keys or conduct field sampling. Students could demonstrate learning through traditional lab practical and paper exams, or utilize website design, portfolios, video, or brochures. Expectations for learning specific content such as species identification would remain despite the myriad of student-selected learning activities and products.

I believe that adopting a constructivist approach can provide diverse, creative, and interesting learning spaces without negatively impacting student course evaluations or student achievement of core course outcomes. However, great care and effort must accompany an embrace of the learning paradigm to reduce the turmoil that emerges with more freedom in the classroom. A focus on student-centered learning bodes well for recapturing the wonder of the natural environment that initially brings students to the field by stimulating students to follow their curiosity within the framework of formal course requirements (Thompson et al. 2003).

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Rotenone Use in North America (1988–2002)

Introduction

The American Fisheries Society (AFS) Fish Management Chemicals Subcommittee (FMCS) conducted surveys of governmental agencies in North America in 1998 and 2001 to determine use patterns and issues (McClay 2000, 2002). Here I report on a follow-up survey covering 2001 and 2002 and on 15 years (1988–2002) of data from the three surveys.

Methods

In the current survey, 95 questionnaires were sent to 83 jurisdictions in 69 agencies representing all 50 states, 2 U.S. territories, 11 Canadian provinces and territories, 4 federal agencies, and 1 Native American tribe. Information was requested on the quantity of rotenone used, treatment objectives, and issues. I also queried the interest for a proposed training program on the use of fish management chemicals and a new liquid formulation that has significantly less petroleum-hydrocarbon solvent.

Multiple responses from the same agency were consolidated into one response (e.g., responses for five U.S. Fish and Wildlife Service [USFWS] regions were consolidated). Quantities of rotenone are reported as kg of active ingredient (AI). One gallon of liquid rotenone (2.5% synergized or 5%) contained 0.1909 kg of AI for applications made through the year 2001 and 0.175 kg of AI for applications made in 2002. One pound of 5% powdered rotenone contained 0.0227 kg AI, although some lots of "5%" powder may actually contain up to 7.5% rotenone. One pound of Carp Management Bait® contained 0.0273 kg AI for all years.

Results and Discussion

Response

Seventy-six responses (80%) were received from 64 agencies (93%) representing 49 states, 2 U.S. territories, 10 Canadian provinces and territories, USFWS, U.S. Department of Agriculture Forest Service (USFS), and National Park Service (NPS). The response rate in the current survey (80%) was slightly below the 82% and 87% obtained in the previous surveys (McClay 2000, 2002). Sixteen surveys were sent to the 7 regional offices of the USFWS and 9 surveys were sent to the regional offices of the USFS. Eight responses (50%) were received from 3 USFWS regions and 4 responses (44%) were received from 4 USFS regions. One state (Tennessee) and 1 Canadian province (Newfoundland) did not respond.

Scope of use

Rotenone was used by 29 states, 2 Canadian provinces (Alberta and New Brunswick), and 2 federal agencies (NPS and USFWS) during 2001–2002. During the 15-year survey period, a total of 38 states and 5 provinces used rotenone and it was used annually in at least 26 states and 1 Canadian province. Rotenone has been used by governmental agencies in at least 35 states for more than 50 years (McClay 2000). Twelve states have not used rotenone in the past 15 years (1988–2002): Arizona, Connecticut, Hawaii, Massachusetts, New Hampshire, New Jersey, New Mexico, Ohio, Oklahoma, Pennsylvania, Rhode Island, and Vermont. Seven Canadian provinces have not used rotenone in the past 15 years (1988–2002): Manitoba, Newfoundland, Nova Scotia, Northwest Territories, Ontario, Prince Edward Island, and Saskatchewan. Carp Management Bait® was used in only 4 states (Iowa, Idaho, Illinois, and Louisiana) in 1998, 1999, and 2001.

Quantities used and water treated

A total of 4,261 kg of rotenone were used by governmental agencies during 2001–2002, with a total of 112,124 kg used for the 15-yr period (Table 1). The quantities used during 2001 and 2002 were the lowest in the last 15 years (Figure 1). The reasons for the low use could not be determined from the survey responses but are likely related to stressed governmental budgets. Overall, there has been a general decrease in the volume of standing water treated, but an increase in the length of flowing water treated; in 2002, 44 hm^3 and 257 km were treated compared to a yearly average of 109 hm^3 and 168 km treated during the period 1988–1997.

The total amount of rotenone used annually (all formulations) was highly variable during 1988–2002 (Figure 1), likely a function of sporadic use by several high consumption states. Eleven states and 1 Canadian province accounted for 89% of the rotenone used during the period 1988–2002 (Table 2). In 1988, 2 states (California and Minnesota) used 56% (1,958 kg and 2,265 kg, respectively) of the total (7,573 kg). In 1989, Wisconsin used 61% (9,701 kg) of the total (15,964 kg). In 1990, Utah used 79% (20,764 kg) of the total (26,139 kg), all on 1 project (Strawberry Reservoir). In 1991, 2 states (California and Utah) used 60% (2,865 kg and 3,225 kg, respectively) of the total (10,162 kg). And in 1997, California used 42% (4,519 kg) of the total (10,683 kg).

There were no obvious trends in the quantities of liquid or powder used during the 15-year period

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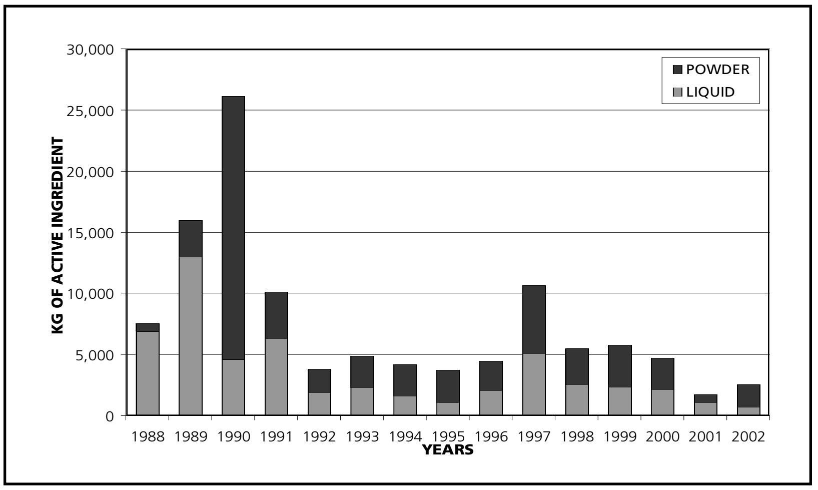
Table 1. Amount of rotenone used (kg AI) in the United States and Canada by water type and formulation from 1988–2002. Actual kg of powder used may be slightly more than reported because some lots of powder contain up to 7.5% rotenone.

Water type	Total use (kg)			
	Powder	**Liquid**	**Carp bait**	**All formulas**
Standing	58,226	50,733	7	108,966
Flowing	207	2,951	0	3,158
Total	**58,433**	**53,684**	**7**	**112,124**

Figure 1. Amount of rotenone used (liquid, powder, and carp bait) in North America (1988–2002).



1988–2002 (Figure 1). Most of the rotenone used (97%) was applied to standing waters (Table 1). In standing waters, the use of powder rotenone only slightly exceeded the use of liquid rotenone (53% vs. 47%). Use of Carp Management Bait® was negligible as only 4 states used almost 7 kg (Louisiana in 1998, 2.7 kg; Illinois and Louisiana in 1999, 3.3 kg; and Iowa, Idaho, and Illinois in 2001; 0.7 kg).

Uses of Rotenone

The principal reasons for the use of rotenone in 2001 and 2002 remained unchanged from the 1988–1997 (McClay 2000) and the 1998–2000 survey (McClay 2002). These were quantification of fish populations (34% of the waters treated), manipulation of fish populations to maintain sport fisheries (27%), and treatment of rearing ponds (17%). Rotenone also played an important role in the eradication of exotic species (10% of the waters treated) and in the restoration of threatened and endangered species (7%), although the quantity used was not large.

The average number of waters treated annually for all purposes decreased 12% for the period 1998–2002 compared to 1988–1997 (483 vs. 423). For these periods, the average number of waters treated annually to manipulate fish populations for maintenance of sport fisheries declined the most, from 42% of the total (1988–1997) to 27% (1998–2002). The average number of rearing facilities treated annually (for these periods) increased (from 14% to 22 %), as did treatments to remove exotic fish (from 3% to 10%). The average number of waters treated annually to quantify populations remained essentially unchanged (31% vs. 30%) during these periods. The reasons for the changes could not be determined from the survey responses.

Rotenone Treatment Procedures

Agencies were asked if they used specific treatment procedures. The results indicated that for the 5-year period 1998–2002 (compared with the period 1988–1997), more agencies performed environmental assessments (54% vs. 47%), monitored treatments with bioassays (51% vs. 44%), and monitored treatments with water samples for chemical analysis (33% vs. 27%). However, fewer agencies neutralized with potassium permanganate (56% vs. 74%).

Issues facing users of rotenone

Data from this and the two previous surveys (McClay 2000, 2002) show that an increasing proportion of U.S. and Canadian agencies are addressing a variety of issues when using rotenone (Table 3). Further, these agencies have been required to address more of those issues and the issues had greater significance than reported in previous surveys. However, two of the most significant issues continue to be (1) public notification and education and (2) public health.

Training

Sixty-seven percent of the respondents to the 2001–2002 survey indicated they felt that training for the application of rotenone would be beneficial. Sixty-five percent indicated that they would participate in such training if it were available through AFS or USFWS. In response to that interest level, the FMCS and USFWS developed a 5-day training program in cooperation with the National Conservation Training Center

Table 2. Largest users of rotenone from1988–2002 (quantities are in kg of active ingredient).

State/Province	15 year total use (kg)	% of total use	Cumulative %	Average annual use (kg)
Utah	26,705	23.8%	23.8%	1,780
Washington	17,528	15.6%	39.4%	1,169
Wisconsin	12,411	11.1%	50.5%	827
Minnesota	12,142	10.8%	61.3%	809
California	9,464	8.4%	69.7%	631
Michigan	4,272	3.8%	73.5%	285
Quebec	3,630	3.2%	76.7%	242
Illinois	3,517	3.1%	79.9%	234
North Dakota	2,883	2.6%	82.5%	192
Nebraska	2,754	2.5%	85.0%	184
Iowa	2,567	2.3%	87.3%	171
Arkansas	2,283	2.0%	89.3%	152
Other	11,968	10.7%	100.0%	798
Total	**112,124**			

Table 3. Proportion of fish and wildlife agencies that have addressed specific issues during three survey periods and the relative significance scores (0=Not Significant; 5=Most Significant) for the two most recent surveys.

	% of Agencies (Significance)		
Issue	**1988-1997**	**1998-2000**	**2001-2002**
Public notification and education	32%	64% (2.4)	64% (2.2)
Liability or property damage	15%	33% (0.7)	52% (1.2)
Public health	43%	58% (1.5)	57% (1.9)
Surface or ground water quality	32%	52% (1.2)	59% (1.6)
Air quality	9%	24% (0.4)	30% (0.6)
Residue in fish	22%	33% (0.5)	46% (1.1)
Animal welfare—fish	32%	36% (0.6)	54% (1.2)
Animal welfare—wildlife	30%	36% (0.6)	55% (1.3)
Animal welfare—reptiles and amphibians	NA	42% (0.9)	55% (1.3)
Animal welfare—invertebrates	28%	42% (0.7)	50% (1.1)
Collection and disposal of dead fish	48%	70% (1.2)	59% (1.5)
Public opposition	NA	NA	55% (1.5)
Regulations	NA	NA	61% (1.8)

(NCTC) in Shepherdstown, West Virginia. The first class was held in fall 2003 with a subsequent class held in spring 2004. For a description of the class and schedule, contact the NCTC (http://training.fws.gov/) and request information on "Rotenone and Antimycin Use in Fish Management" (Course Code FIS2132).

New liquid formulation

Eighty-five percent of the respondents indicated they would consider using a formulation (currently registered in the United States as CFT Legumine®) that contains significantly less petroleum-hydrocarbon solvents and 17% indicated they thought their use might increase.

Conclusions

Rotenone remains an important fishery management tool. In the last 15 years (1988–2002) it has been used by a total of 38 states and 5 Canadian provinces, continuing a trend of use by at least 35 states for more than 50 years (McClay 2000). Eleven states and 1 Canadian province accounted for 89% of rotenone use.

Although an earlier survey (McClay 2000) pointed to a decline in use over the 10-year period 1988–1997, trends in the total quantity of rotenone used over time are less evident with the addition of another 5 years of data. Wide fluctuations in annual use and the amount of different types of waters treated (standing or flowing) each year make it difficult to identify trends.

Most rotenone use (>93% annually) occurs in standing water. Overall, the volume of standing water treated generally has decreased, but the length of flowing water treated has increased.

More agencies are addressing public health and environmental issues in their planning and execution of projects. Agencies apparently are responding to these issues by performing more environmental assessments and monitoring more treatments with bioassays and water samples for chemical analysis. The majority of responders felt that training for the use of rotenone would be beneficial and 65% indicated that they would participate in such training.

Many of the issues faced by North American fisheries managers using rotenone have to do with public health, air and water quality, residues in fish, and animal welfare. One contributing factor is that the liquid formulations currently available contain significant quantities of petroleum-hydrocarbons. A liquid formulation used in Europe contains significantly less hydrocarbon compounds. This formulation is currently registered in the United States under the trade name CFT Legumine® (available through Prentiss Incorporated) and is undergoing field-testing in the United States. It is likely that, depending on cost, many agencies would switch to the new liquid formulation to minimize the public issues they face when proposing fisheries management projects involving the use of rotenone.

Acknowledgments

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economic growth **forum**

Economic Growth and Environmental Protection:
A Clarification about Neoclassical Economics

Note: A longer version of this article will appear in the Spring 2005 issue of the AFS Socioeconomics Section Newsletter, available at www.fisheries.org/socioecon.

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A recent article (Czech et al. 2004) and the "economic growth forum" series of articles (Czech and Pister 2005) in *Fisheries* consider the relationship between economic growth and environmental protection, specifically fish conservation. These articles highlight an important social concern: the unfettered pursuit of profit by business firms will lead to the degradation of the environment and the overuse of natural resources, including fisheries. Czech and Pister claim that mainstream economists ignore the problem: "Neoclassical economists, micro and macro, typically opine that there is no practical limit to economic growth and, as a corollary, no inevitable conflict between economic growth and environmental protection (including fish and wildlife conservation)." As neoclassical economists, we take issue with this statement and would like to address the possible misperception among fisheries professionals about the appropriate role of economists and economics in the allocation of scarce fishery resources.

We will introduce the economic way of thinking regarding natural resources and the environment. We consider microeconomics and macroeconomics. We hope to leave readers with the impression that neoclassical economists do believe there is a conflict between economic growth and environmental protection. However, our policy solutions are very different than those proposed in recent *Fisheries* articles.

The economic analysis of the environment appears in all mainstream introductory economics courses and textbooks (Mankiw 2004). The standard analysis is due to A.C. Pigou (1920). The economic analysis of pollution concludes that markets fail to allocate resources efficiently; specifically, production in unregulated "dirty" industries will be too high and the prices of these products will be too low because they do not reflect the "social cost" of pollution. The standard economic solution is to tax the output in the polluting industry. The tax leads to lower output, higher prices, and less pollution.

Standard introductory economics courses and textbooks also address another market failure: the overharvesting of fisheries and other open-access resources. The standard analysis is due to H. Scott Gordon (1954). An absence of property rights provides an incentive to extract the resource before competitors do so, and also ignores the impact of current harvest on future recruitment. This "race for the fish" leads to the overharvesting problem (i.e., the "tragedy of the commons"). The standard economic solution to this problem is to tax effort, in other words, tax the activities that lead to overharvesting. The economic goal is to maximize the sustainable value of the fishery.

Macroeconomists also have not ignored environmental issues. First, some background: the goals of macroeconomics are economic growth, full employment, and price stability. Economic growth is typically measured by increases in the gross domestic product (GDP). Economic growth or contraction is nothing more than the summation of all purchasing decisions made by individuals and companies. Economic growth is largely driven by peoples' individual decisions, not public policy. Government policy can only help influence growth by affecting some of the variables behind people's purchasing decisions: interest rates, taxes, and public spending.

Gross domestic product is considered a good proxy for economic well being. However, economists have long been aware that GDP does not do a good job of measuring many activities that contribute to economic well being such as child rearing, leisure activities, and the enjoyment of environmental amenities. These issues are common in the standard introductory economics courses and textbooks. Mainstream macroeconomists have been busy trying to correct these problems in the measurement of economic well being. One of the thrusts of this research is to incorporate the value of the environment and the cost of natural resource use into a "green GDP."

Macroeconomists also consider the positive and negative effects of environmental protection on economic growth. Mainstream macroeconomists have documented important costs of environmental pollution such as the negative health impacts and the resulting losses in labor productivity. Environmental regulation leads to improved labor productivity and increases in economic growth. On the other hand, environmental regulation diverts business firm resources away from production, raising the cost of production and consumer prices, and leading to lower economic growth.

Another macroeconomic issue is the relationship between GDP and environmental quality. One type of relationship is the environmental Kuznets curve, the statistical finding that environmental quality rises as GDP rises for some measures of quality. However, some pollutants do not obey the Kuznets curve pattern and among neoclassical economists, the jury is still out concerning the environmental Kuznets curve. It is a reach to state that neoclassical economics use the environmental Kuznets curve to justify unregulated economic growth.

A basic understanding of neoclassical economics would lead one to conclude that neoclassical economists recognize the conflict between economic growth (i.e., consumption) and environmental protection (e.g., fish conservation). The neoclassical microeconomic perspective toward environmental protection is that society should pursue clean environments and limitations on natural resource use so that the difference between the benefits and costs of these pursuits is maximized. One of the goals of macroeconomics is the achievement of economic growth. Neoclassical macroeconomists believe that environmental regulation is a drag on economic growth and many argue for reduced regulation. However, others argue that unfettered development damages labor productivity and economic growth, and reduces the overall quality of life. It is with this latter group that we, the fisheries community, must work to heighten awareness of the economy's impact on fisheries.

It is too simple to state that neoclassical economics pushes the goal of economic growth while ignoring the benefits of environmental protection. We believe that members of the American Fisheries Society (AFS) should not lose sight of the ability of neoclassical economics to prescribe improved policies for environmental protection and natural resource use.

The AFS should, and does, strive to increase the value people hold for fisheries and the environment so that such costs are to be considered as part of every purchase. The AFS also can educate the public about how some purchases produce worse environmental impacts than others. When people agree with these concerns, economic policy and consumption behavior will change.

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Brian Czech, Phil Pister, and Lisi Krall respond:

A Special Class of Neoclassical Economists

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The clarification by Whitehead et al. that "neoclassical economists do believe there is a conflict between economic growth and environmental protection" is very encouraging. We wish neoclassical economists across the board were more vocal and united on this point. Whitehead et al. should be commended for acknowledging that they, at least, recognize the conflict.

We are concerned, however, that the neoclassical paradigm may not suffice for addressing the conflict, even when the conflict is acknowledged. The neoclassical focus on correcting for market failure will make markets more efficient, but efficiency is far from sufficient for sustainability. The size of the economy must be addressed in addition to how efficient it operates.

Also, readers should not assume that Whitehead et al., who specialize in fish conservation, speak for neoclassical economists at large. Prominent neoclassical economists are known for denying the conflict between economic growth and environmental protection. Lester Lave, for example, of Carnegie-Mellon Institute took the position that there is no conflict between economic growth and environmental protection in a televised Earth Day debate against Brian Czech.

Similarly, Czech once asked Robert Lucas, Nobel laureate and then-president of the American Economic Association, if there was a limit to economic growth. Lucas replied, "No, that's what technology is for." Neoclassical growth economists such as Lucas promote a theory of perpetual growth and are politically appointed to councils of economic advisors.

We who seek an AFS position on economic growth can agree with much of the article by Whitehead et al., with caution. For example, they opine that "It is a reach to state that neoclassical economists use the environmental Kuznets curve to justify unregulated economic growth." We defer to them in measuring the length of the reach, noting only that neoclassical economists have certainly not united to dismiss the environmental Kuznets curve (as it should be) with laws of thermodynamics and principles of ecology. Meanwhile, corporate front groups and politicians are milking the Kuznets curve for all the pro-growth policy it will produce.

Most importantly, however, we are sincerely encouraged to find a more ecologically grounded set of economists in AFS than in many other corners. We already agree on the major thrust of an AFS position on economic growth; i.e., the conflict between economic growth and fish conservation. We look forward to upcoming discussions about potential policy alternatives.