Economic Valuation of Adverse Maritime Pollution Impacts

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- Distinguished Professor of Economics, University of California, San Diego
- Past President & Elected Fellow, Association of Environmental & Resource Economists
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- Author, 8 books, 120+ published papers,
- Named most cited environmental economist in the world
- Principal Investigator on many of the largest environmental economics projects done in U.S. and several other countries, including damage assessments for Exxon Valdez & BP oil spills
- Consultant/advisor to Local, State and U.S. Federal agencies: Agriculture, EPA, Commerce, Energy, Interior, Justice, Forest Service; International: IADB, OECD, UNDEP, WHO, World Bank; Australia, Canada, Malaysia, Norway, United Kingdom

- I have lots of practical experience in working as the economist on policy evaluations and natural resource damage assessments.

- You are encouraged to ask questions at any time if you don't understand or think this is an interesting topic you like know something more about

Outline

- Welfare economic/benefit-cost framework
- Assembling lists of biological, physical & socioeconomic impacts
- Response Costs
- Use of market prices
- Overview of tools for nonmarket economic valuation
- Benefit transfer exercises
- Contingent valuation (CV)
  - Including discrete choice experiments (DCE)

- Canonical contingent valuation study examples
  - Southern California DDT contamination
  - Oil spills: Exxon Valdez, California
- Discrete choice experiment example
  - Malaysia forest preserve
- Production function analysis
  - Wetlands & tropical cyclone property damage reduction
- Travel cost analysis and averting behavior
  - Recreational fishing in Alaska
- Hedonic pricing
  - Wages, property, and products

A Very Short History of Welfare Economics

- Long standing, intense debates from the time of Adam Smith (1776) on the nature of economic value:
  - Money/prices versus goods/actions
  - What is observable and what is not observable
- Bentham (1789) pushes concept that people maximize "utility"
  - Rather than money
- John Stuart Mills (1861) pushed concept that governments should maximize aggregate utility
  - Greatest good for the greatest number of people
  - Utilitarian perspective underlies modern benefit cost analysis
- Alfred Marshall (1890), Arthur Pigou (1920) & John Hicks (1943) show how to cast physical changes into monetary equivalence
- Pareto (1894) & Kaldor (1939) actual vs. potential compensation

Conceptual Underpinnings of Welfare Economics

- Central issues
  - How is economic value determined?
    - Market prices versus trade-offs agents are willing to make
  - What has economic value?
    - Directly supplied by private agents vs. (implicitly) by government
  - How to compare economic value across agents?
    - What is role of preference heterogeneity and income?
  - How to compare economic welfare be across time?
    - What is economic value of the same change in different years?
  - How is aggregate economic welfare for policy determined?
    - Does a societal social welfare function exist?

Jules Dupuit's (1844)

- French engineer who worked on roads and water supply
- Asked two important questions
  - At what price was utility maximized for an (uncongested) bridge?
  - Where should a new bridge be located to maximize utility?
- First question led to answer: utility maximized at a zero price
  - Concept turns out equivalent to consumer surplus later put forward by Marshall
- Second question lies the heart of non-market valuation
  - **Thought experiment:** Given two existing bridges on a river and knowledge of where people live, where do you place a third bridge?
  - **Answer:** Place third bridge where it minimize aggregate travel time for trips using any one of the three bridges.
  - **Economic value:** hours of travel time saved x value of a saved hour of time

Applied Welfare Economic Framework

- Starting point
  - Define **status quo level** (often referred to as **baseline**)
- Consider gains and losses from change from status quo
  - Gains are usually the "benefit" side of a **benefit-cost analysis**
  - Losses are usually the "cost" side of a benefit-cost analysis
  - Desirable policy changes involve benefits > costs
- Assessing an injury to natural resources from "illegal" pollution is a special type of benefit-cost analysis
  - Event **imposes** costs due to **adverse change** to **status quo**
  - Benefit calculation involves least expensive way to **return** to economic equivalent to **status quo or avoiding similar event**

- Assessing an injury to natural resources from "illegal" pollution is a special type of benefit-cost analysis
  - Event **imposes** costs due to **adverse change** to **status quo**
  - Benefit calculation involves:
    - Determining least expensive way to **return** to the "economic" equivalent to **status quo AND/OR**
    - Economic value of **avoiding** adverse change

Concept of Economic Value

- The two standard measures of economic value depend on desirability of change from status quo:
  - Maximum willingness to pay [**WTP**] for desirable change
    - Example: status quo is **I do not own** a specific bicycle, what is the **largest amount of money** that I would be willing to **voluntarily** give up to get the bicycle
  - Minimum willingness to accept compensation [**WTA**] for undesirable change
    - Example: status quo is that **I do own** the specific bicycle, what is the **smallest amount of money** I would be willing to take in order to **voluntarily** sell it.

Some Additional Background Concepts

- Voluntarily nature of transaction means agent undertaking is better off afterwards than original status quo
  - Agents can be firms, households, individuals
- For the same agent, **WTA > WTP**
- Definition of the status quo in an economic/legal context is known as the **property right**, often termed "**entitlement**"
- Property rights can be held by individual agents or by **society**
  - A maritime accident releasing considerable pollution violates the societal property right to the original (baseline) status quo environmental conditions.
- Conceptually, the economic quantity of interest the minimum amount of compensation [WTA] agents would have demand to voluntarily agree in advance to let the accident happen.

Fundamental Problem

- No known way to obtained a reliable estimate of the WTA of all relevant agents to give up individual and society property rights to not have accident.
  - Basic issue: cannot solve the time traveler problem
- Standard approaches substitute WTP for WTA measures
  - Results economic estimate of the costs imposed by the accident being a lower bound on appropriate WTA measure

Benefit-Cost Analysis

- Initial tasks
  - Determine **all sources of benefits** from prospective change
  - Determine **all sources of costs** due to prospective change
- Relatively straightforward on cost side for many desirable prospective changes.
  - Often just market prices for goods/services need for change
  - More complicated is getting the **time profile** (e.g., maintenance cost) correctly specified.
- Estimating benefits and costs in monetary terms, for changes involving environmental impacts, more complex

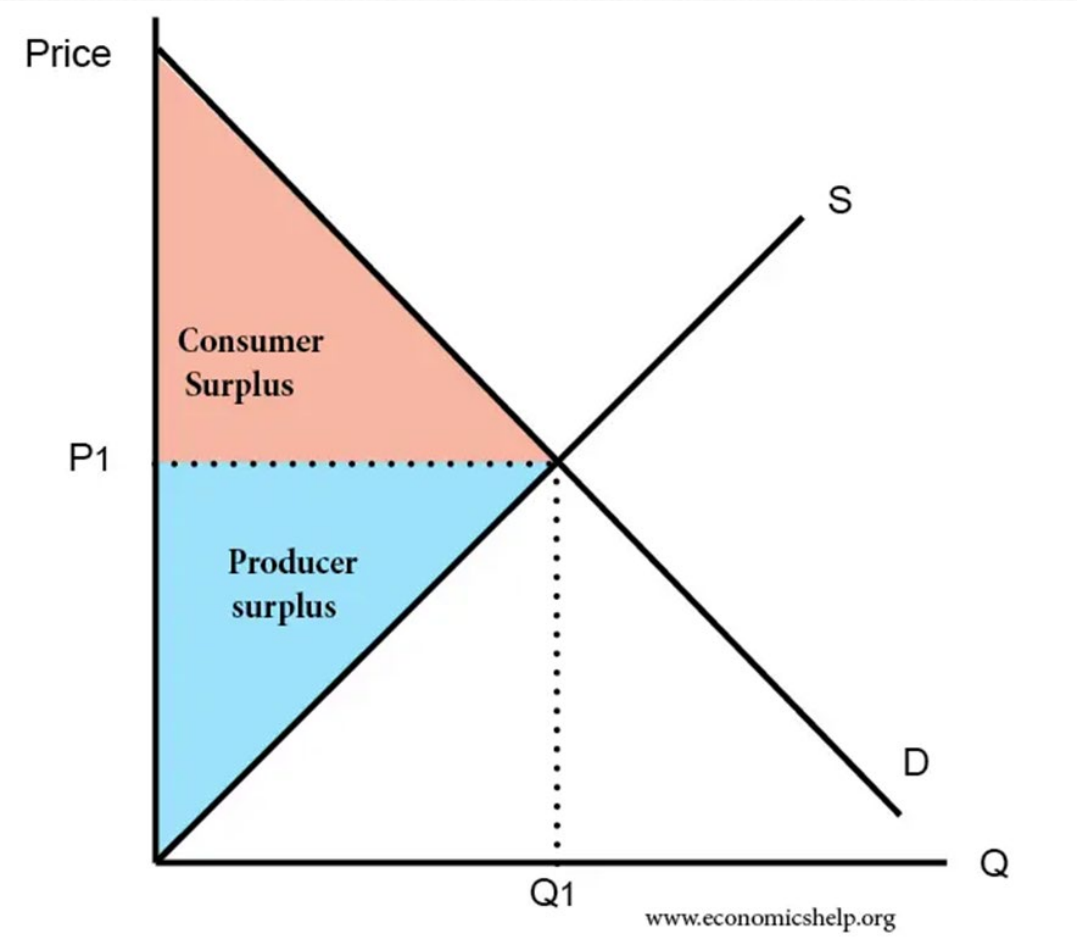
Three Types of Goods/Services

- Private goods/services
  - Provided by private agents (firms, individuals, households)
  - Have a market price that excludes those not paying for obtain the good/using the service
- Quasi-public
  - Provided by government agencies (& non-profits)
  - Has a price but often subsidized or implicit and it is desirable to exclude some agents due to congestion externality
    - Camp site in nature area with entrance fee
- Pure public good
  - Has zero price and it is not desirable to exclude any agent

Use of Market Prices for Private Goods

- Most private goods have an observable market price (MP)
- In a well functioning competitive market:
  - WTP < [Consumer Surplus + MP] < WTA
  - Difference between WTP and WTA typically small (~5%)
    - So only an estimate of consumer surplus is needed
  - Idealized example: bid (WTP) – ask (WTA) spread in stock market for a frequently traded stock
- Many issues with market prices when a good/service category is characterized by substantial quality differences or location specific differences.
  - Price premiums for higher quality/better located goods sometimes hard to recover.

Consumer Surplus & Producer Surplus



- Can be obtained from standard economic approaches to estimating demand and supply curves.

Consumer Surplus

- **Consumer surplus** can be defined as the amount of money the consumer would have been willing to spend for the observed quantity, holding income constant.
  - WTP **is approximately equal to** consumer surplus when prices is zero, which is common for many (quasi)-public goods.
  - WTP holds "**utility constant**" and is sometimes referred to as **Hicksian** consumer surplus to distinguish it from the standard (**Marshallian**) consumer surplus that holds "**income constant**".
  - Divergence between WTA and Marshallian consumer surplus occurs because **WTA is not income constrained**.

Producer Surplus

- Producer surplus is the short-term profit (ignoring fixed cost) the firm makes selling the observed quantity.
  - Amount that a firm needs to be compensated for a short-term revenue loss incurred from not being able to sell their product in order to to be made "whole"

- Compensation rules often approximate by subtracting easy to observe variable cost (e.g., fuel for fishing boasts) not incurred from expected revenue (market price X quantity) if firm had been able to sell product.

Benefit-Cost Formula

- Single change relative to status quo.
- There are i = 1 to N different agents
- There are t = 0 to T different time periods
- Denote benefits to the i_{th} agent in t as B_{it} & cost as C_{it}.
  - Individual agents can experience both benefits & costs.
  - Many agents likely to zero benefits and zero costs
- Discount rate is r.
- Benefit minus costs for change:
- $\Sigma_t\Sigma_i [B_{it}/(1 + r)^t] - \Sigma_t\Sigma_i [B_{it}/(1 + r)^t]$
- Major issues: choice of N, T and r

Choice of N, T and r

- $\Sigma_t\Sigma_i\ [B_{it}/(1 + r)^t] - \Sigma_t\Sigma_i\ [C_{it}/(1 + r)^t]$
- The index i= 1 to N defines the set of agents whose benefits and costs are included in the analysis.
  - Often defined in terms of geography or type of agent
  - Multiple ways of defining (economic, legal/regulatory)
- T, number of years aggregated over has a large influence when benefits and/or costs are long lived or permanent
  - Multiple ways of defining (economic, legal/regulatory)
- r, the larger r the less benefits & cost in later periods matter
  - Typically set by government (using an underlying economic construct) to ensure consistency in evaluating policies

Stylized Example With One Agent

- Assume let T = 3 and discount rate is .05
- Upgrade a sewage treatment plant with costs
  - One time cost of C_0
  - Annual operating costs of C_1 and C_2
- Annual benefits from improved water quality after upgrade
  - B_1 and B_2
- Net benefit calculation is:
  - $\Sigma [B_1/(1+.05) + B_2/(1 + .05)^2] - C_0 + C_1/(1 + .05) + C_2/(1 + .05)^2$

Reference Books

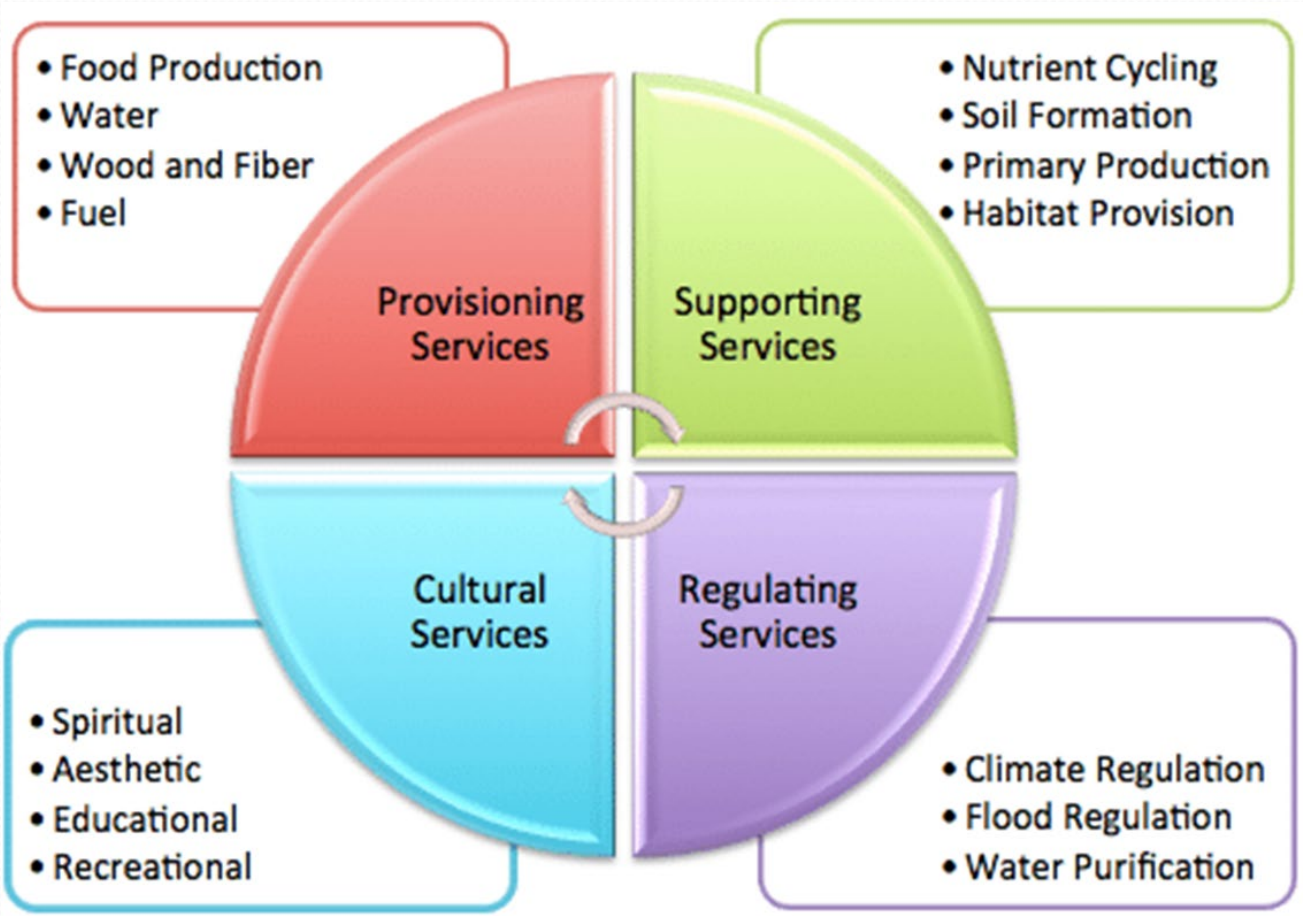
- Deaton and Muellbauer (1980), Economics and Consumer Behavior (Cambridge)
  - Still hard to beat for basic consumer theory
- Just, Hueth and Schmitz (2004), The Welfare Economics of Public Policy (Edward Elgar)
  - Updated version of 1982 classic
  - Most examples agriculture/environment/resources

Assembling Lists of Biological, Physical & Socioeconomic Impacts

- For a desirable change:
  - what good (and bad) things are likely to happen
- For an adverse change:
  - what bad things have happened and likely to happen
- These changes can be characterized in many ways:
  - Type or location of biological/physical impact
  - Sector of the economy
  - Characteristics of good or service
- Which economic valuation approaches should be used depends on these.

Some General Typologies

- Millenium Ecosystem Assessment Typology



Source: Millenium Ecosystem Assessment, 2005.


SUPPORTING
PROVISIONING
CULTURAL
REGULATING
Ecosystem Services
What Nature provides us for free
Food
Soil Formation
Photosynthesis
Biodiversity
Habitat
Stewardship
Aesthetic
Recreation
Education
Clean Air
Store Carbon
Purify Water
Control Flooding
Cool Temperatures
Pollination
Wood
Fish
Clean Water

Conceptualizing Fresh Water Impacts

(Carson and Mitchell, Water Resources Research, 1993)

A TYPOLOGY OF BENEFITS FROM AN IMPROVEMENT IN FRESHWATER QUALITY		
Benefit Class	Benefit Category	Benefit Subcategory (Examples)
Use	In-Stream	Recreational (water skiing, fishing, swimming, boating) Commercial (fishing, navigation)
	Withdrawal	Municipal (drinking water, waste disposal) Agriculture (irrigation) Industrial/Commercial (process treatment, waste disposal)
	Aesthetic	Enhanced Near Water Recreation (hiking, picnicking, photography) Enhanced Routine Viewing (commuting, office/home views)
	Ecosystem	Enhanced Recreation Support (duck hunting) Enhanced General Ecosystem Support (food chain)
Nonuse	Vicarious Consumption	Significant Others (relatives, close friends) Diffuse Others (American public)
	Stewardship	Inherent (preserving remote wetlands) Bequest (family, future generations)

Lists of Potentially Impacts Get Progressively Disaggreggated*

- *X-Press Pearl Sinking Puts a Lens On Seafood Safety in Sri Lankahttps://www.eco-business.com (19 August 2021)

Developing an Initial List of Potential Impacts

- Plan in advance
  - Evaluation of a marine policy proposal
  - Exercise with a hypothetical marine accident

Versus

- Response to an actual marine accident

- Let's sketch a hypothetical marine accident
  - Policy proposals tend be developed slowly
  - Every accident has unique features

Hypothetical Oil Spill

- Fishing trawler collides with cargo ship 5km from Dondra Head
  - Quickly known: trawler taking on water and leaking oil & cargo ship damaged but not currently taking on water or leaking oil
- Initial responder: Coast Guard
- New parties: ship owners & their insurers
  - Ships often owned by a shell company whose only asset is ship
  - With liability limitations, shipper and government's interest diverge
- Governmental agencies with early potential involvement:
  - National Aquatic Resources Research and Development Agency, Central Environmental Authority, Department of Fisheries and Aquatic Resources, Department of Wildlife Conservation, and Marine Environment Protection Authority.
- Later involvement: Ministry of Justice

Main Lesson from Planning Exercise

- What is likely to happen (over time)?
- What should happen?
- Difference between the answers to these two questions identifies weakness in current capacity and coordination
  - Likely to highlight data needs
  - Can be repeated with different types of accidents
  - Relevancy can be enhanced by model-based prediction of likelihood of different accident types of different locations

Four Immediate Impacts Likely

- (1) some (unknown) quantity of oil released into coastal waters
- (2) (unknown) number of km of shoreline likely to be oiled
- (3) local areas on shoreline are likely to be closed for recreation
- (4) local area near spill likely to be closed for commercial fishing

- (1) some (unknown) quantity of oil released into coastal waters
  - Prevention: what is being done to contain the oil around trawler?
    - Is there a response plan already in place and who is responsible for it?
    - It is almost always cost effect to quickly booming off a ship leaking oil.
  - Is there a simple per barrel penalty for spilling oil independent of actual measurable impacts.
    - Hard to assess biological/economic impacts of any particular small spill, but cumulatively do substantial harm, particularly in busy ports.
    - Makes opening an investigation easier.
- Near term
  - How much more oil leaking out is likely under (reasonable) the best and worst case scenarios.
- Long term: Does accident pose a potential risk of long-term oil leakage?

- Related question: what else is likely to cause harm that is on the trawler and cargo ship if either sinks?

- (2) (unknown) number of km of shoreline likely to be oiled
  - Known: best predictor of amount of harm done by an oil spill is generally km of oil shoreline not the amount of oil spilled.
  - How is this going to be measured?
    - Characteristics of oiling: e.g., type of oil, uniform vs. spotty oiling
    - Plan for taking samples and pictures
  - Baseline issue: was there already oil there from other sources
    - How to distinguish this oil from it and attribute harm to it
- Potential for a large number of km of coastline to be oil?
  - Is there a physical oceanography model to predict likely path?
  - How is plan for samples and pictures going to scale upward?

- (3) local areas on shoreline are likely to be closed for recreation
  - What areas (e.g., beaches, recreational fishing) need to be closed due to the threat of contact/contamination with oil?
  - How to measure number of lost recreational trips from closure?
    - Straightforward if already being routinely counted in some manner
    - Alternatives: baseline information + observers (pictures of closed beaches)
  - What other types of businesses are impacted?

- If km of impacted shoreline expand, how will monitoring effort be scaled up and maintained over time.
  - Formal modeling effort will be need to account of substitution

- (4) local area near spill likely to be closed for commercial fishing
  - What fishing boats are impacted?
  - What was their catch in the recent past?
  - What were market prices for species of fish previously caught?
  - Can fuel cost not incurred be easily estimated?
  - **Economic loss:** catch reduction x market value – typical fuel costs
  - Who can file for this loss and what "proof" is needed?

- How long is closure likely to last & is its area likely to expand?
  - Longer term: need to take account of redeployment of boats fishing impacted to less desirable (e.g., distance, catch)

Small vs. Large Accidents

- Small accidents
  - Science side relatively simple: document that spill occurred, estimate size of spill in barrels, document spill area, show spill caused response actions like closures
  - Economic side: show agents (household, fishers, business, government agencies) incurred cost as a result of the spill

- Large accidents: same as a small spill, but increase reliance on:
  - (a) large scale monitoring to demonstrate extent and duration
  - (b) modelling efforts to provide a large picture of extent/duration
  - (c) modelling efforts to estimate impacts to ecosystem services
  - (d) modelling efforts to provide ecosystem service estimates for economic modelling

Response Costs

- Parties who can incurring
  - Ship owner & insurer
  - Coast guard
  - Emergency response vessels
  - Other government agencies
  - Private businesses
  - Households
- Three phases: short term, medium term, long term

Rules for Recovering Losses

- In thinking about these four initial impacts, work through how existing legal framework will assist or hinder government's need to make the public "whole" after the accident.
  - Limitations on what types of harm are compensable
  - Limitations on who can file claims and when
  - Limits on which economic valuation tools can be used

- Almost every country after a large maritime accident has found their existing legal framework to be inadequate to the task of making the public whole.
  - A major issue is the inadequacy of international conventions and compensation pools for maritime shipping coupled rules that designed to favor shippers and quick resolution.

Further Response Issues

- Who controls the approval process for reimbursement?
  - Shipper/Insurer vs. government agency
  - If government agency which one
- Does government have a fund for response activities prior to reimbursement?
  - Government agencies, particular scientific ones, often lack financial resources to quickly scale up to handle large accident
- Are there criteria (e.g., reasonable cost, meeting professional standards) response claims have to meet?
  - Are voluntary labor hours by households reimbursable?
- When does response end and restoration begin?
- Is long term monitoring considered to be a response cost?

Measuring Economic Value of Any Good Or Service

- Economic value are inferred by analysts from the choices that individual agents make.
- Choices that agents make are constrained by the prices offered to them and income available to them.
- Choices reveal lower and upper bound estimates of economic value cast in terms of willingness to pay (WTP).

How Do All Economic Valuation Techniques Work?

- Observe agent choice(s) in a **particular context** and extract information with implications about how agent values good.

- Example: Agent observed paying 400 LKR for a kilo of rice
  - Implies agent's WTP ≥ 400 LKR & less than their income
  - If agent did not buy: 0 ≤ WTP < 400 LKR
  - Interval information from shop purchases or survey choice
  - Repeated choice occasions at different prices tightens the WTP interval
- Context elements can be important
  - Changing income, price of substitutes, amount of rice at home can all influence choice and hence the interval in which WTP falls.

Dose Response Curve Analogy

- Randomly assign households to a small number of different prices (poison-horizontal axis). If buy good record as "yes" (alive-vertical axis) and if they don't buy record as "no" dead. **Area under curve: WTP**.

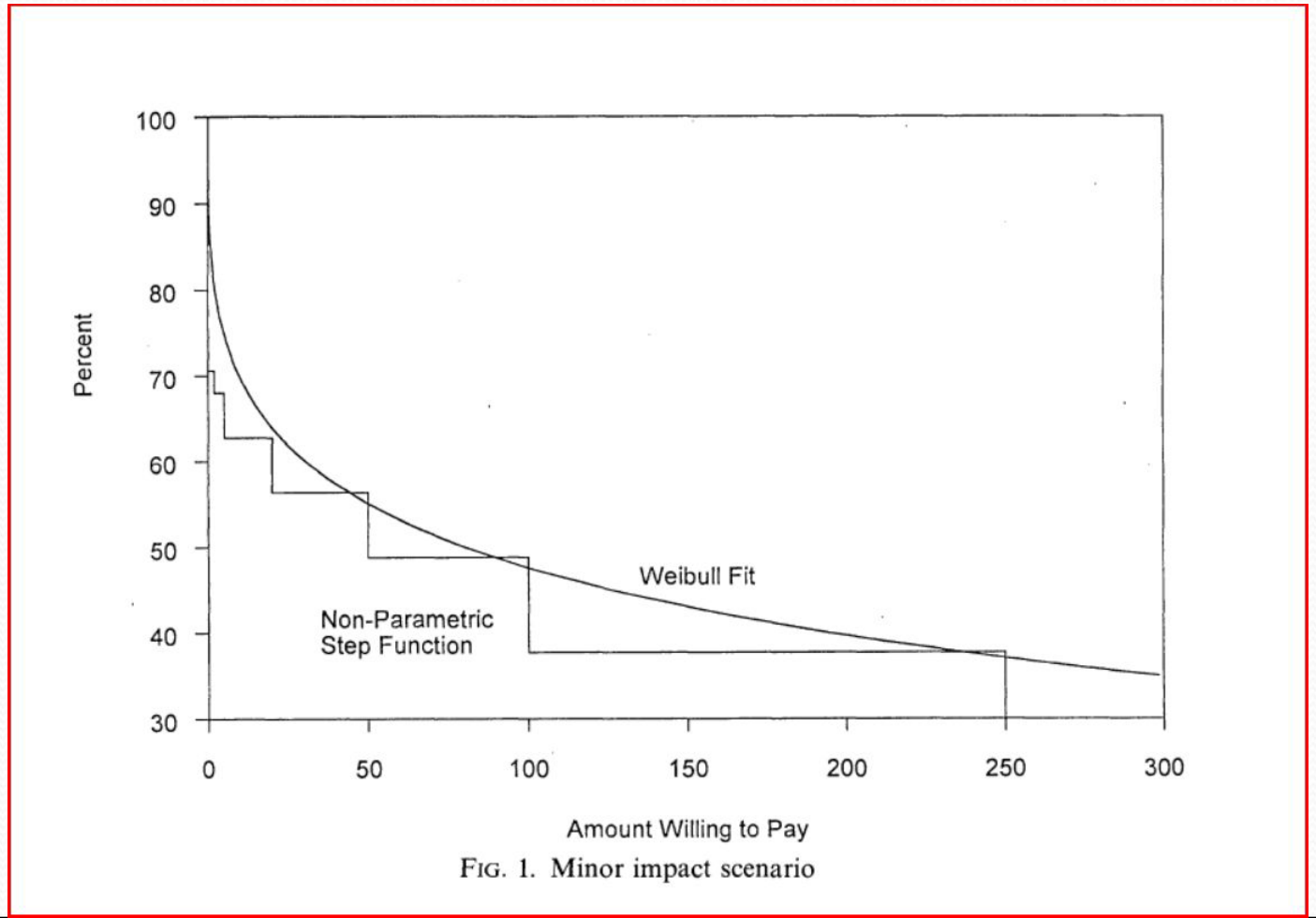


FIG. 1. Minor impact scenario

Use of Market Prices

- Economic valuation of an early sudden fisheries closure
  - Catch reduction x market value – typical fuel costs
- Assumptions:
  - Boat in area closed would have caught (quantity, quality & species distribution what they had been catching recently before closure.
    - Requirement: boat log books and/or landing receipts by species
  - Market prices stable before and after accident because closure area small and people do not react to threat of contamination.
    - Often not plausible, so substitute market prices immediately before closure
  - Boats stay in port. Because closure sudden, don't pay for fuel but do have to pay for labor (e.g., catch share agreement).
- Assumptions breakdown as area/duration of closure expands.
  - Can be dealt with but requires lots of data & complex modelling.

Tourism

- Hotels, short-term rental properties, tour operators in area directly impacted by accident get immediate cancellations.
  Economic loss:
  - **Cancelled days X Booking rate – not incurred expenses**

- Assumptions
  - All reductions in room/tour sales reflected in cancellations
  - Booking rates not influenced by accident
  - No impacts outside directly impacted area
  - Only impact is on property/tour company owners.
- Assumptions break down as impacted area and duration expand.
  - Can be overcome with substantial data and complex modelling.

Implications

- Direct use of market prices is of limited applicability for most types of injuries likely to be observed.
- Become increasingly unreliable as area impacted by the accident its duration increase.
  - Can be dealt with using complex but standard economic modelling designed to deal with “reputational” injuries.
  - Situations where market prices “endogenous” in a larger context.
- Does not handle losses:
  - Loss of sales by suppliers to directly impacted businesses
  - Loss of sales by complementary businesses such as restaurants
  - Loss of tax revenue by government
- All these indirect or induced impacts can be dealt with using a regional input-output analysis framework.

Demand for Monetized "Benefit" Estimates For Outputs of Government Programs

- History of being able to place an increasing array of outputs of government water projects into monetary terms
- U.S. Presidential Executive Orders starting with Reagan in 1981 mandating a benefit-cost analysis for all major regulations
- Similar actions, either mandated or encouraged, by many U.S. states and many national governments
- Similar requirements by the World Bank and several of the regional development banks
- Legal cases involving harm to public goods for which a government agency is the trustee for the good

Benefit-Cost Analysis Without Non-Market Valuation

- Any impact not able to be expressed in monetary terms is typically counted as "$0".

- Until early 1980's, a dam project valued electricity & water withdrawals at market price and flood prevention at averted property damage cost.
  - Not valued in monetary terms were outdoor recreation and ecosystem impacts.

- Obviously, a benefit-cost analysis ignoring two of the most important impacts is (close to) useless.
  - Clearly favors dam building even when ecosystem harm is large

Tools for Nonmarket Valuation

- Several ways to categorize
  - Value specific impacts & then aggregate versus undertaking holistic assessment
  - Direct impacts on people (closed beaches, fisheries) versus impacts via diffuse changes in ecosystem services
  - Revealed behavior versus stated (survey) preferences
  - Type of loss: private, quasi-public, or pure public good
  - Inclusion of passive use considerations
    - Also called bequest, existence, non-use value, stewardship values
- Many of these of these are closely tied to whether a survey-based approach is used.

Inclusion of Passive Use Considerations

(Also known by other terms such as existence or nonuse values)

- Consider a large oil spill that occurs in a little visited remote part of the country where national parks, nature preserves, and/or marine protected areas have been set up.
  - Any economic valuation estimate of the direct losses associated with the spill **has to be small** because the **number of agents being aggregated over is small**.

- This is not true of passive use. Number of households in the country who would be willing to pay the cost of putting into place measures that would prevent and/or contain such a spill **may be large**.

Determinants of Economic Value

- Attributes of the good
- Stable characteristics of buyers (e.g., number, income)
- (Transient) attributes of the situation of choice

Nonmarket Valuation Tools for Most Other Impacts

- Contingent valuation (CV) surveys can be used to create "missing" markets of interest & hence most flexible method
  - Most commonly implemented approach.
- Other approaches rely on appropriate surrogate market:
  - Production function approach: environmental good influences output of marketed good. Temperature & ag prod.
  - Travel cost analysis: more likely to visit a recreation site the less expensive it is to travel to it.
  - Averting behavior: purchase good to reduce some type of risk
    - Buy facemask to reduce chance of getting COVID-19
  - Hedonic pricing approach: env. attributed "bundled" into marketed good. Better air quality increases house prices

Useful References for Nonmarket Valuation Tools

- Champ et al., *A Primer on Nonmarket Valuation* , 2nd ed. (Springer, 2017).
- Freeman, Herriges and Kling, *The Measurement of Environmental and Resource Values: Theory and Methods*, 3rd ed. (Rutledge, 2014).
- Johnston, R., et al. *Benefit Transfer of Environmental and Resource Values: A Handbook for Researchers and Practitioners* (Springer, 2015).
- Maler and Vincent, *Handbook of Environmental Economics: Valuing Environmental Changes* (vol. 2) (Elsevier, 2006).

Using Surveys to Value Public Goods: The Contingent Valuation Method

Mitchell and Carson (RFF, 1989)

- Codified the literature on non-market valuation
  - Welfare economics of pure public, quasi-public, private goods
  - Stated (forward looking) preference vs. reveal (past) behavior
  - Relationship of CV to other non-market valuation techniques based on revealed behavior (e.g., hedonic pricing, travel cost)
- Moved away from emulating a private goods market to that of emulating a political market for public goods
  - Emphasized potential importance of non-use values
- CV scenario seen as a "constructed" marketed design to help respondents make an informed decision
- Provided typology of threats to CV's reliability and validity

Benefit Transfer Exercise

- Most estimates of the economic value of nonmarket impacts are developed in benefit-transfer exercises.
  - Such exercises take benefit estimates from existing academic literature and "adjust" them to the specific context where they are needed.
  - Reason: original nonmarket valuation studies are expensive and often require considerable time to complete.
- Adjustments are for differences in area population characteristics and differences between impact originally studies and the one of current interest.
  - When there is a substantial number of literature estimates in an area, often takes the form of a formal meta-analysis.
- Nonmarket value estimates underlie periodically updated **official** government estimates to use for:
  - **Value of time, value of a statistical life, value of QALYs, value of different types of outdoor recreation days, social cost of carbon**

Starting a Benefit-Transfer Exercise

- Find studies that place an economic value on a non-marketed good similar to the one of now of interest.
- Google scholar is a good starting point
  - www.scholar.google.com
  - Read current papers to find earliest studies, search on papers that cite them to help locate others.

- Use databases that have been put together of nonmarket values estimates
  - Some of these are quite broad in coverage
  - Others are narrowly focused

Français

EVRI Environmental Valuation Reference Inventory

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About EVRI

What is EVRI?

The Environmental Valuation Reference Inventory (EVRI) is a searchable compendium of summaries of environmental and health valuation studies. These summaries provide detailed information about the study location, the specific environmental assets being valued, the methodological approaches and the estimated monetary values along with proper contextualization. The EVRI database now contains over 5,000 summaries of valuation studies and information from new studies is being added on an ongoing basis.

ESVD

Ecosystem Services
Valuation Database

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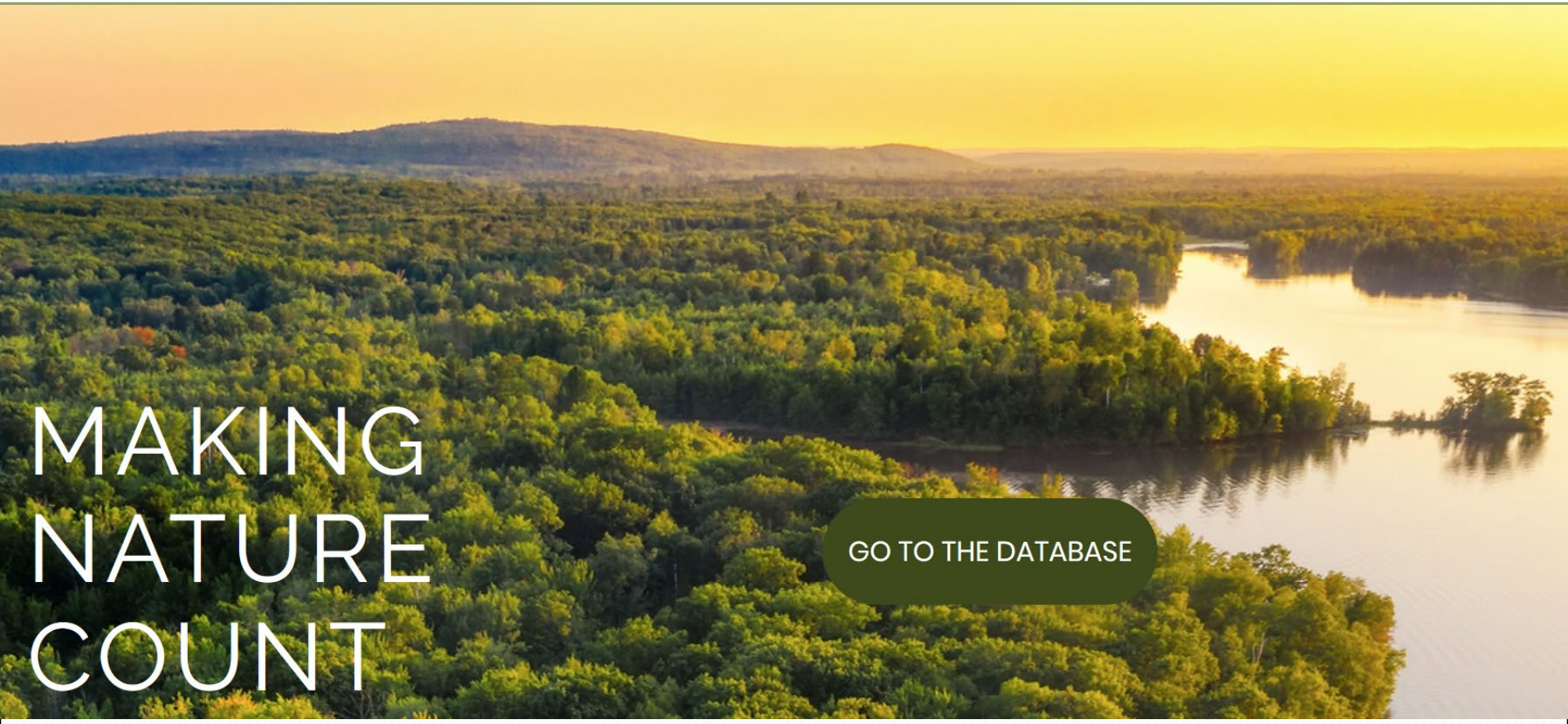

Stanford University

natural capital PROJECT

NATURAL CAPITAL PROJECT

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College of Forestry

Recreation Use Values Database

No Name Lake, by Camille Brooks

Navigation

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- Benefit Transfer Guides and Additional Readings
- Brief History
- Draft Papers

Our Academic Departments

How CV Surveys Differ From Conventional Surveys

- A long interview focused on a single issue
- Educate respondents about the issue
- Asks respondents to make an economic tradeoff reflected in choice involving the issue

Contingent Valuation (CV) Survey

- Simulate an ideal marketplace for a public good.
- Offer that good for sale at a specified cost.
- Ask respondents whether they favor or oppose provision at that cost.
  - Cost amounts randomly assigned to respondents.
- Responses allow estimating the value of the good to the population in dollars.
  - Traces out demand curve (% favoring as function of cost).

Key Elements of a CV Scenario
(Mitchell & Carson, 1989)

- Details of the good
  - Status quo, change from it described in understandable terms
  - Depicting change in terms of attributes often helpful
- Provision
  - Method & provider
- Payment mechanism
  - Frequency and type (e.g., sales tax increase)
- Elicitation format
  - Range from open-ended WTP questions to complex discrete choice experiments (DCE)
- All of these could and, often, should influence a CV-based estimate of economic value.

The Southern California DDT CV Survey

(Carson, Hanemann, Kopp, Krosnick, Mitchell, Presser, Ruud & Smith, 1994)

- Explain injuries
- Explain a plan to repair the injuries
- "Given a cost of $X to you if implemented, would you vote for or against it?"
- Measure potential predictors of vote

Questionnaire Development

- 14 focus groups (N=10 each)
- 100+ one-on-one interviews
- 12 pretest surveys (N=50 each)
- 4 pilot studies (N=400 each)

Total: 2,340 PREPARATORY respondents

A-12. The federal, state, and university scientists I mentioned earlier have conducted studies of the effect of this deposit  . They know that DDT and PCBs can build up in the bodies of some fish and birds when the food they eat has these chemicals in it.

According to the scientists, the only animals that are affected by this deposit are the four species I told you about. This is because they all feed in this particular place.

SHOW CARD G

This drawing shows how this happens.

STOP UNTIL R HAS HAD A CHANCE TO LOOK AT CARD G

These  are small animals that live in the sediment on the ocean bottom. When they get food from contaminated sediment, they absorb DDT and PCBs into their bodies.

When they are eaten by other larger animals, like this fish which is feeding on the bottom  ,

the DDT and PCBs can be absorbed into the body fat of the larger animals.

(As you know,) This also happens when larger fish eat the smaller fish  ,

when birds like this eat contaminated fish,

or when birds like this eat other birds that have eaten contaminated fish.

REMOVE CARD G

Although the amount of DDT and PCBs in the bodies of the four species is high enough to affect their ability to reproduce, the amount is not enough to affect the adult fish or birds in any other way.

California Coastal Areas

South Coast


Barstow
Lancaster
Point Conception
Santa Barbara
Ventura
San Miguel Island
Santa Cruz Island
Los Angeles
Anacapa Islands
Santa Monica Bay
Santa Rosa Island
CHANNEL ISLANDS
Long Beach
San Pedro Bay
Huntington Beach
Santa Barbara Island
NORTH
Oceanside
San Nicolas Island
Santa Catalina Island
San Clemente Island
San Diego
0 10 20
Miles
Mexico

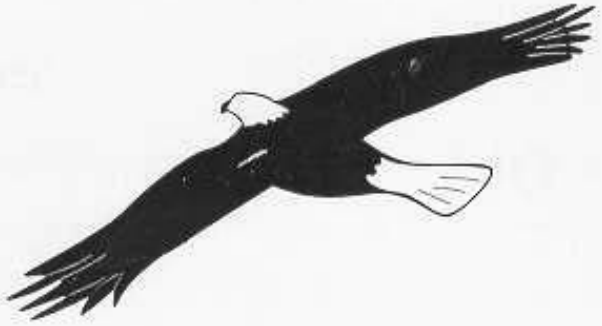
SOUTH COAST FISH AFFECTED

WHITE CROAKER

KELP BASS
(Calico Bass)

SOUTH COAST BIRDS AFFECTED

BALD EAGLE



PEREGRINE FALCON

Is species currently listed as endangered in California?

White Croaker

Kelp Bass

No

Bald Eagle

Peregrine Falcon

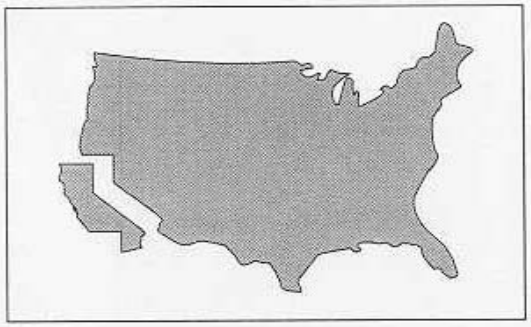
Yes

Population of

BALD EAGLE

PEREGRINE FALCON

Rest of California and Rest of United States



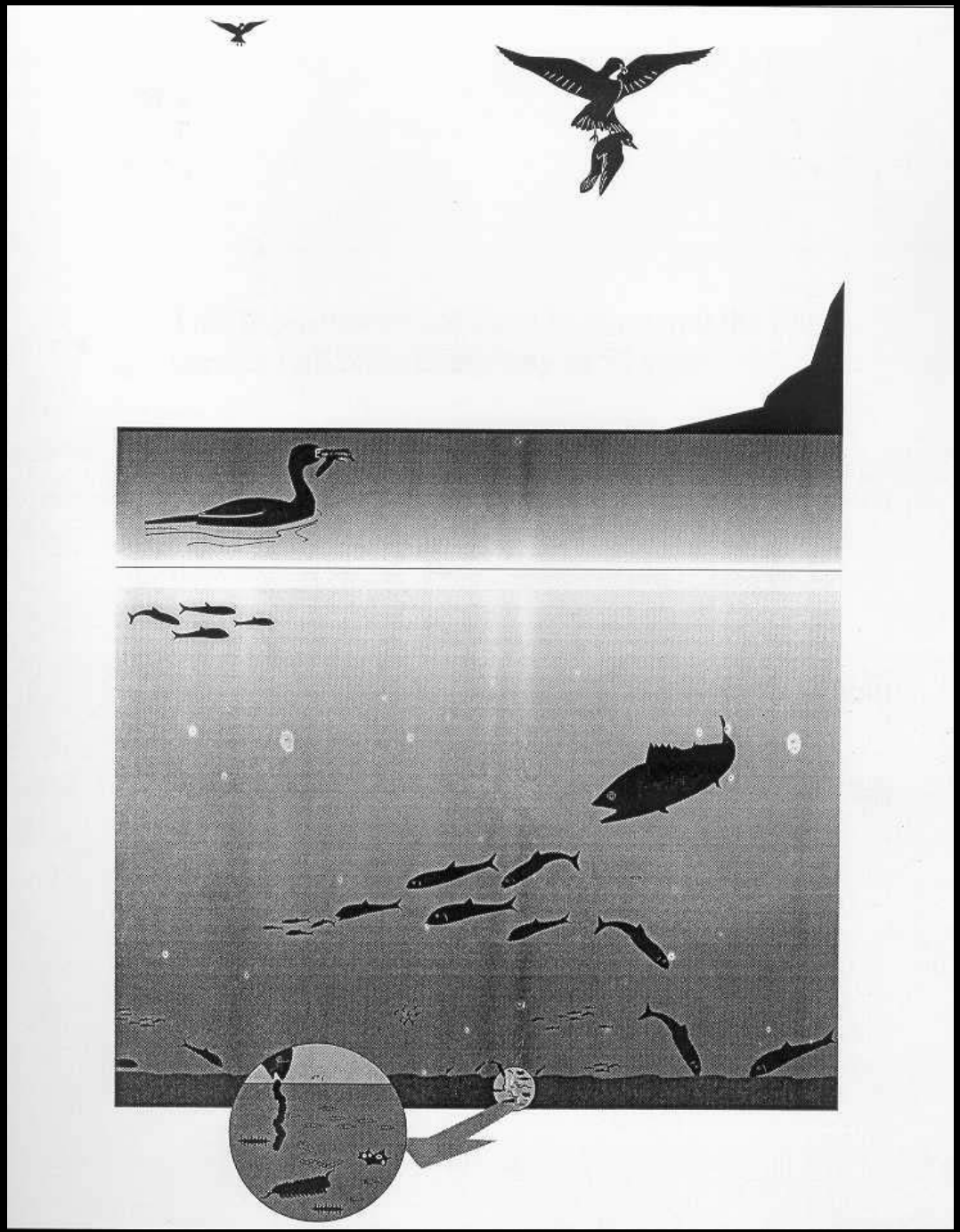
Increasing

Along the South Coast

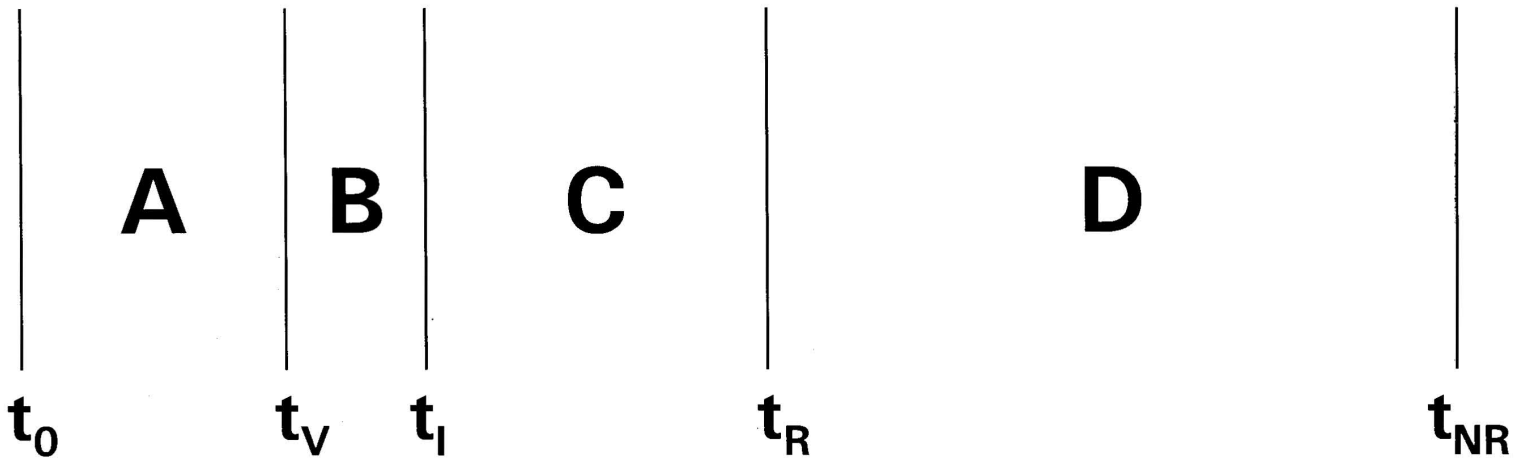
Not Increasing

CARD F


Lancaster
Point Conception
Santa Barbara
Ventura
San Miguel Island
Santa Cruz Island
Anacapa Islands
Santa Rosa Island
Los Angeles
Santa Monica Bay
Long Beach
Huntington Beach
Santa Barbara Island
San Pedro Bay
CHANNEL ISLANDS
NORTH
Oceanside
Santa Catalina Island
San Nicolas Island
San Clemente Island
San Diego
0 10 20
Sewage treatment plant
Long Beach Harbor
Los Angeles Harbor
San Pedro Bay
DDT & PCB deposits on ocean floor



ILLUSTRATIVE TIMELINE



t_0 time of release

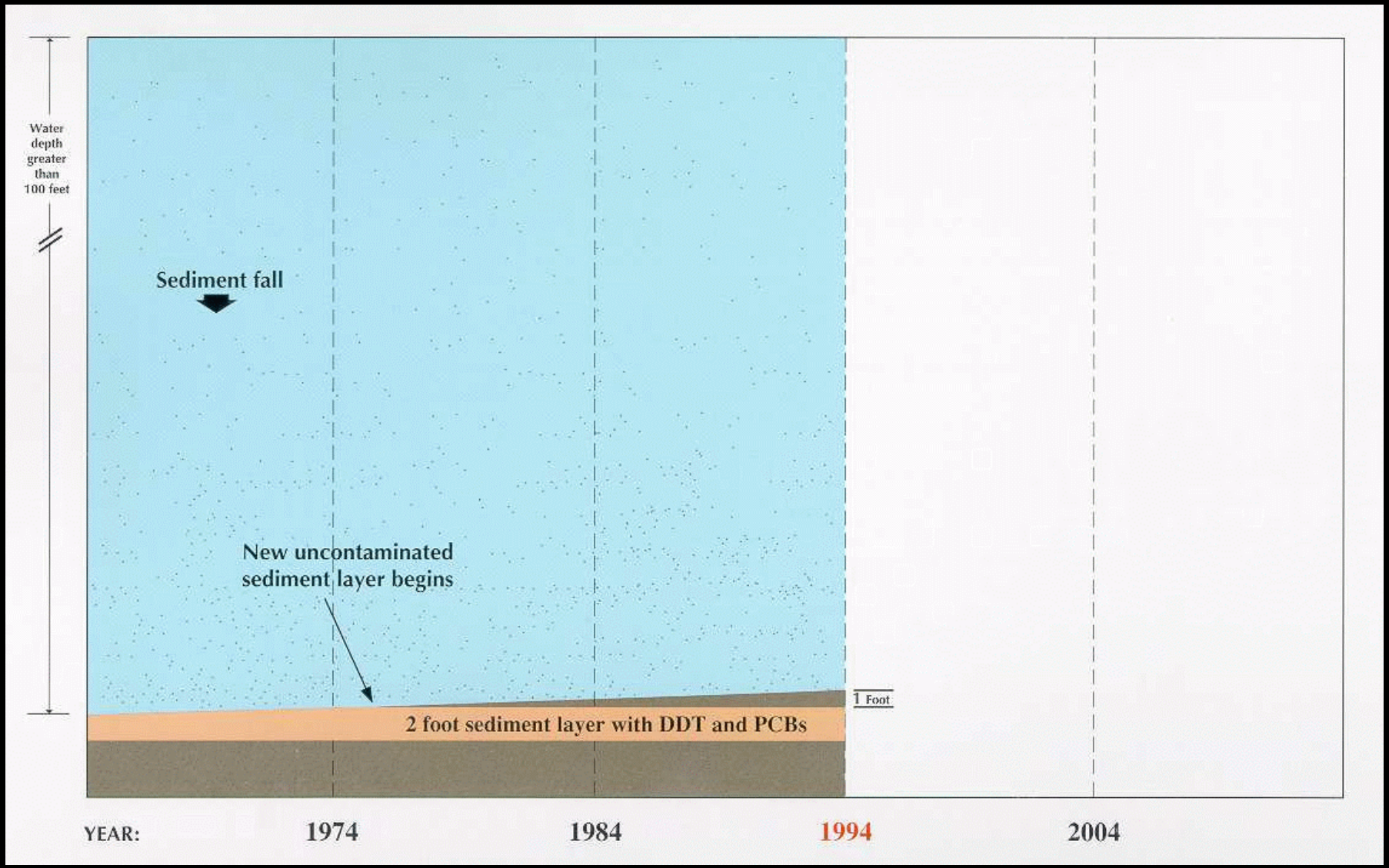
t_V time of valuation

t_I time of implementation of restoration plan

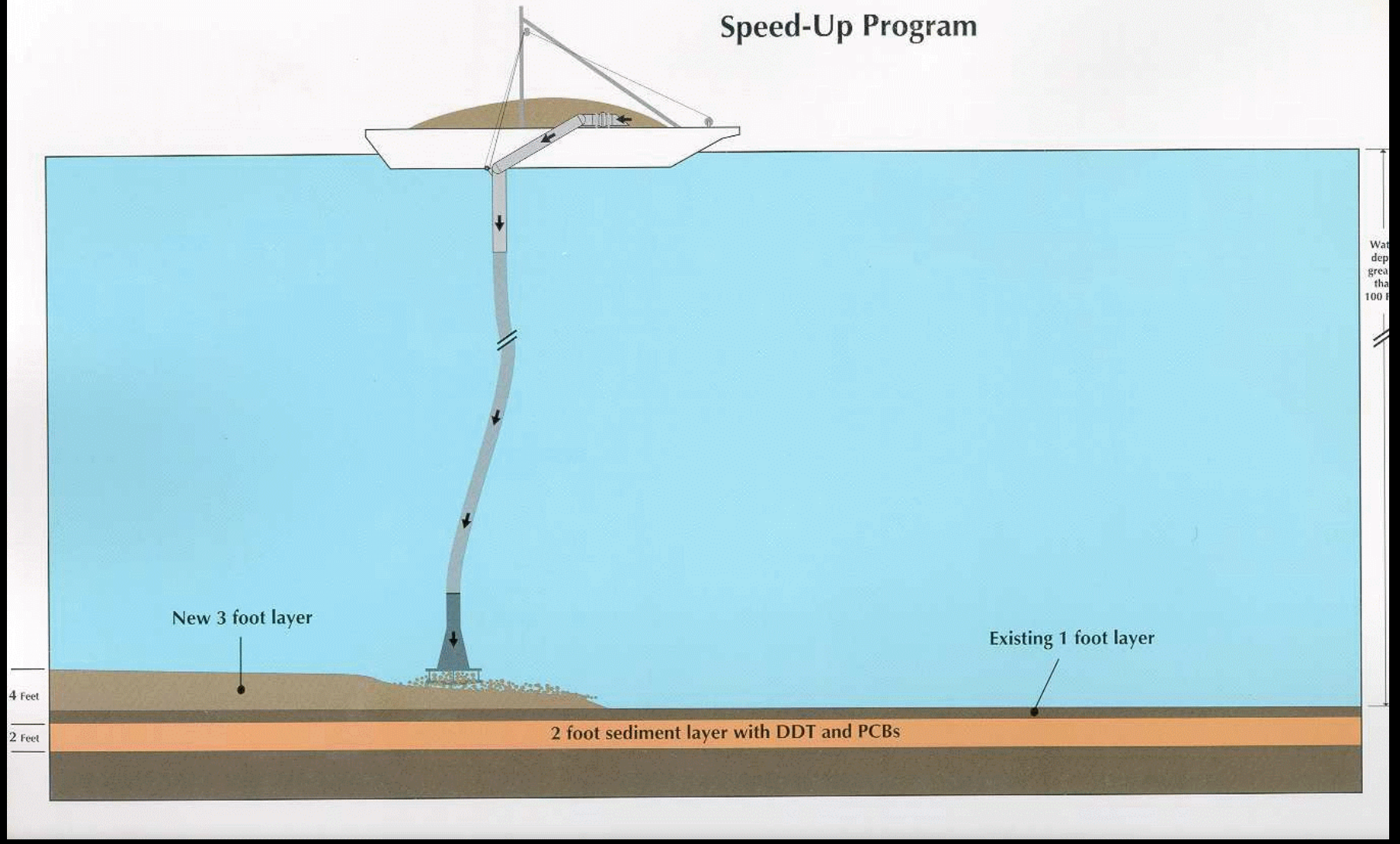
t_R time of complete recovery with restoration plan

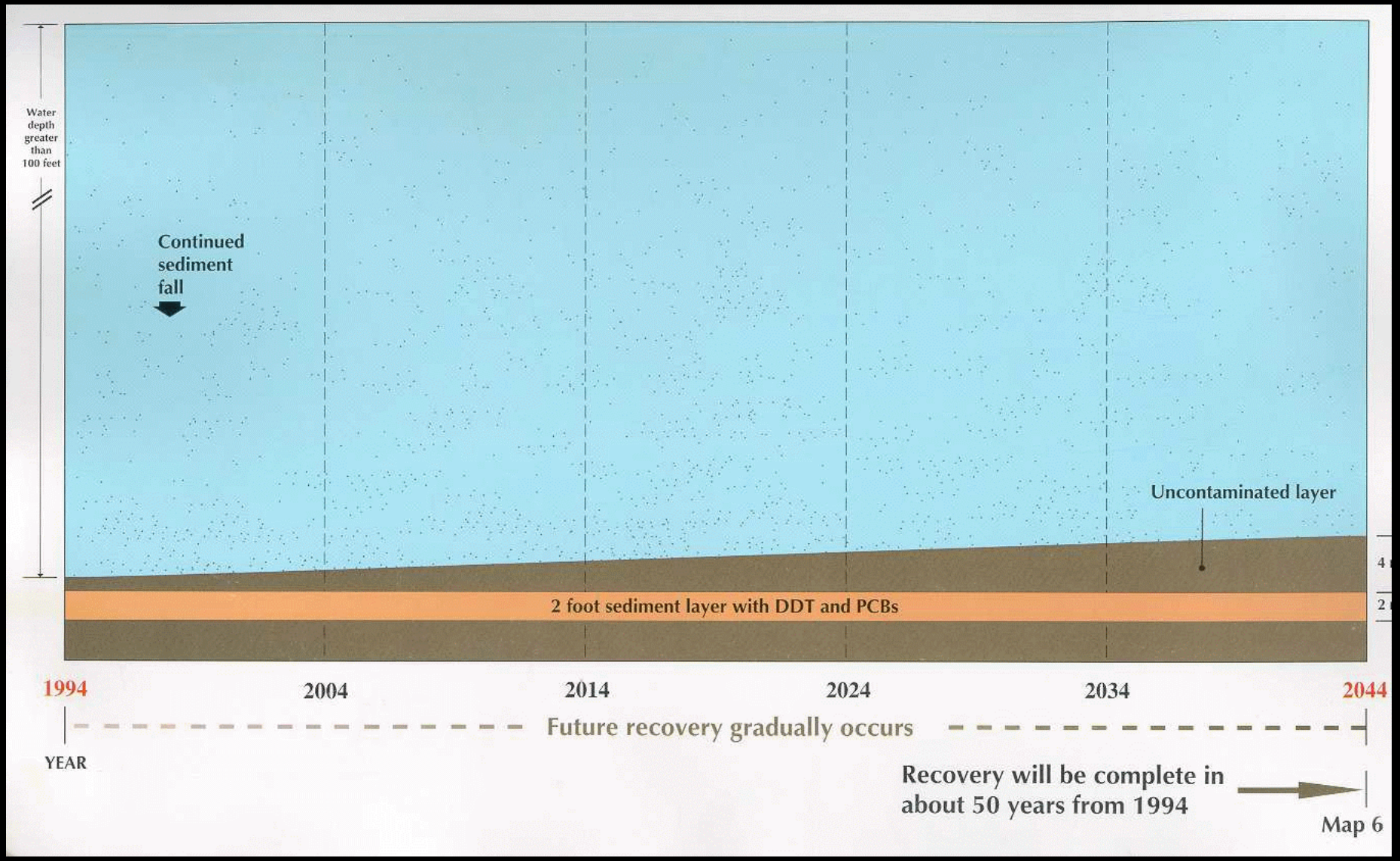
t_{NR} time of complete natural recovery

ASSUMING ACCURATE TIMELINE PRESENTED TO RESPONDENTS:
WITH NATURAL RECOVERY, INTERIM LOSS USE = A + B + C + D.
WITH RESTORATION, INTERIM LOSS USE = A + B + C.


Water depth greater than 100 feet
Sediment fall
New uncontaminated sediment layer begins
1 Foot
2 foot sediment layer with DDT and PCBs
YEAR:
1974
1984
1994
2004

Speed-Up Program




Water depth greater than 100 feet
Continued sediment fall
Uncontaminated layer
2 foot sediment layer with DDT and PCBs
1994
2004
2014
2024
2034
2044
Future recovery gradually occurs
YEAR
Recovery will be complete in about 50 years from 1994
Map 6

Primary Measure

- We are now interviewing people to find out how they would vote if this program to speed up recovery were on the ballot in a California election.

- At present, the program to speed up the covering of the contaminated sediment is estimated to cost your household a total of $25. Your household would pay this as a special one-time tax added to next year's California income tax.

- If an election were being held today and the total cost to your household would be a one time additional tax of $25, would you vote for the program to speed up recovery or would you vote against it?

Questionnaire Structure

- Tell respondent about pre-existing conditions.
- Provide respondent with details about the problem.
- Propose a solution.
- Describe cost to respondent of implementing solution.
- Respondent choses: implement it or not.
- Measure respondent's perceptions of the good.
- Measure respondent's attributes.

Key Design Elements

- Consequences of the decision
- Order of information
- Alternative uses of money
- Limited income
- Substitutes
- Breaks and opportunities to ask questions
- Visually engaging, understandable language
- Accountability
- Referendum format
- Measure reasons why people vote yes/no
- Measure acceptance of the scenario
- Give people the opportunity to change “yes” votes
- Measure perceived pressure on respondents
- Interviewer evaluates respondent attention, interest, effort

Split Sample Manipulations For Assessing Validity

- Cost Manipulation
  - $10, $25, $80, $140, $215
- Scope of Good Manipulation
  - 2 Fish with 15-year natural recovery
  - 2 Fish and 2 Birds with 50-year natural recovery

Data Collection

- Representative sample of California households
- Face-to-face interviewing in respondent homes
- 60 interviewers
- Sampling and data collection by WESTAT
- March 8 – August 23, 1994
- Response rate: 73% (N=2,810)

Results of Core Choice Question

Cost	Favor Program
$10	59.4%
$25	51.4%
$80	37.0%
$140	31.7%
$215	24.7%

Perceived Injury Seriousness X Scope

Table 10.1 Version by Perceived Seriousness of Injury

Version	Not serious	Not too serious	Somewhat Serious	Very Serious	Extremely Serious
Base (row percent)	97 (5.3%)	355 (19.3%)	713 (38.7%)	475 (25.8%)	201 (10.9%)
Scope (row percent)	138 (14.6%)	287 (30.4%)	315 (33.4%)	140 (14.9%)	63 (6.7%)
$\chi^2_{(4)} = 148.90; p < 0.001$					

Test of Sensitivity to Scope

Version	Favor Program
Base	36.6%
Scope	21.0%

WTP Estimates:

Base: $63.24 ($2.54) **Scope:** $32.02 ($2.82)

t-test of equality vs. Base > Scope: (7.17, $p > .001$)

Predictions: Higher WTP for …

- Higher income (likely non-linear)
- More positive attitude toward the environment
- Believe the damage is more serious
- Believe the clean-up program is more effective
- Believe the tax amount will end up being less
- Support taxation to pay for public programs
- Does not pay California taxes
- Have confidence in California government
- May be more directly affected by the deposit

Probit Model Predicting WTP

- Tax Price (log) -.40***
- Income (if <$35,173; log) .17***
- Income (if > $35K, < $150K; log) .15***
- Income (if > $150K; log) .11**
- Does not pay California taxes .49***

(continued …)

*p<.10 **p<.05 ***p<.01

Regressors Predicting WTP 2

- Extremely important to protect coastal areas .15**
- Increase government spending on endangered wildlife .42***
- Decrease government spending on endangered wildlife -.27**
- Strong environmentalist .24***

(continued …)

Regressors Predicting WTP 3

- Natural recovery will take longer .53***
- Natural recovery will be quicker -.29***
- Program will be completely or mostly effective .60***
- Program will not be effective -1.26***
- Asked about how program will work or what it will cost -.30***

(continued …)

Regressors Predicting WTP 4

- Participates in saltwater boating or fishing or goes to the beach .22***
- Birdwatcher .18**
- Often watches TV shows about animals .19***
- Household often eats fish .18**
- Lives in Los Angeles or Orange Co. .17**
- Lives North of San Francisco -.25**

Summary: Southern California DDT CV Study

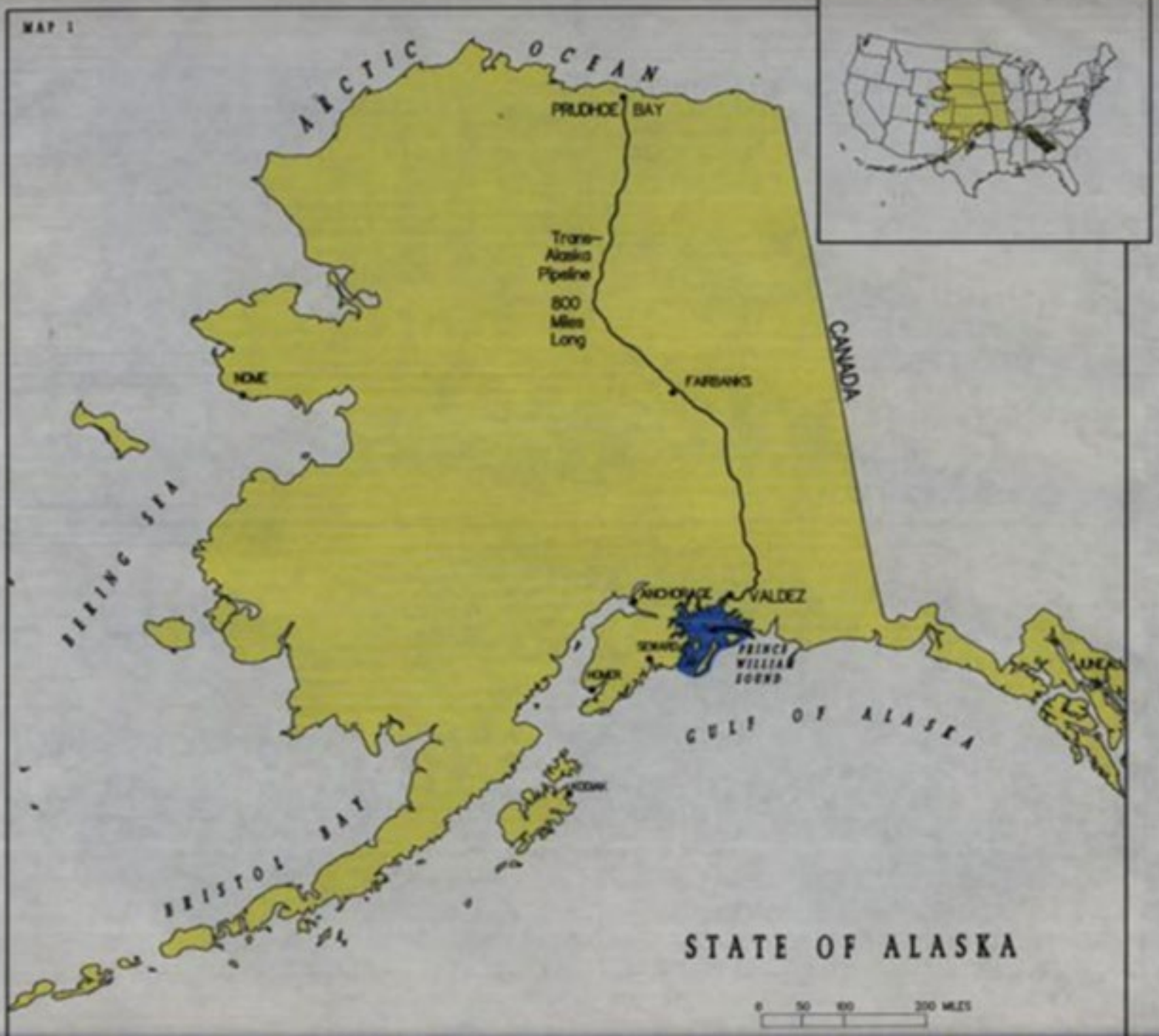
- Response to binary voting question is:
  - sensitive to randomly assigned cost
  - sensitive to scope of good treatment, and
  - sensitive to differences in household income.
- Vote influenced by observed covariates, including environmental attitudes, resource usage, and location.
- Vote influenced by judgments about remediation plan.

Exxon Valdez CV Study

- Conduct for the legal case of the State of Alaska and U.S. government trustees (NOAA, U.S. DOI)
  - Strongly motivated by DC Court of Appeals decision in Ohio v. U.S. DOI. Ruled public needed compensated for lost “passive use” [non-use] values to be made “whole” and CV was appropriate for measuring if “reliable”.
- In-person survey of 1043 respondents from a national representative sample administered by Westat

Survey Opens

- Respondents told general purpose of survey is to explore the public's views on policy issues.
- Respondents asked a set of standard (national) questions on support/opposition for spending on different government programs.
- Respondents told issue that will be the main focus of the survey is a policy proposal to prevent another oil spill similar to the recent Exxon Valdez oil spill.
  - Starts with showing respondents where the Exxon Valdez spill took place.


MAP 1
ARCTIC OCEAN
PRUDHOE BAY
Trans-Alaska Pipeline
800 Miles Long
CANADA
NOME
FAIRBANKS
BERING SEA
ANCHORAGE
VALDEZ
SEWARD
PRINCE WILLIAM SOUND
KODIAK
GULF OF ALASKA
BRISTOL BAY
STATE OF ALASKA
0 50 100 200 MILES


MAP 3
PRINCE WILLIAM SOUND
VALDEZ
Trans-
Alaska
Pipeline
Oil Terminal
Columbia
Glacier
BLIGH
REEF
Tanker
Lanes
CORDOVA
PRINCE WILLIAM SOUND
From here to Valdez is 75 miles
GULF OF ALASKA

Setting Where Spill Took Place

A PORT OF VALDEZ AND VALDEZ NARROWS

B COLUMBIA GLACIER ON PRINCE WILLIAM SOUND

Describing Wildlife Harmed

- Respondents are:
  - Shown photographs of the different types of wildlife impacted
    - Species of birds
    - Marine mammals
  - Provided information on:
    - Estimates of the number of different types killed
    - Population sizes
    - Time for population to rececover

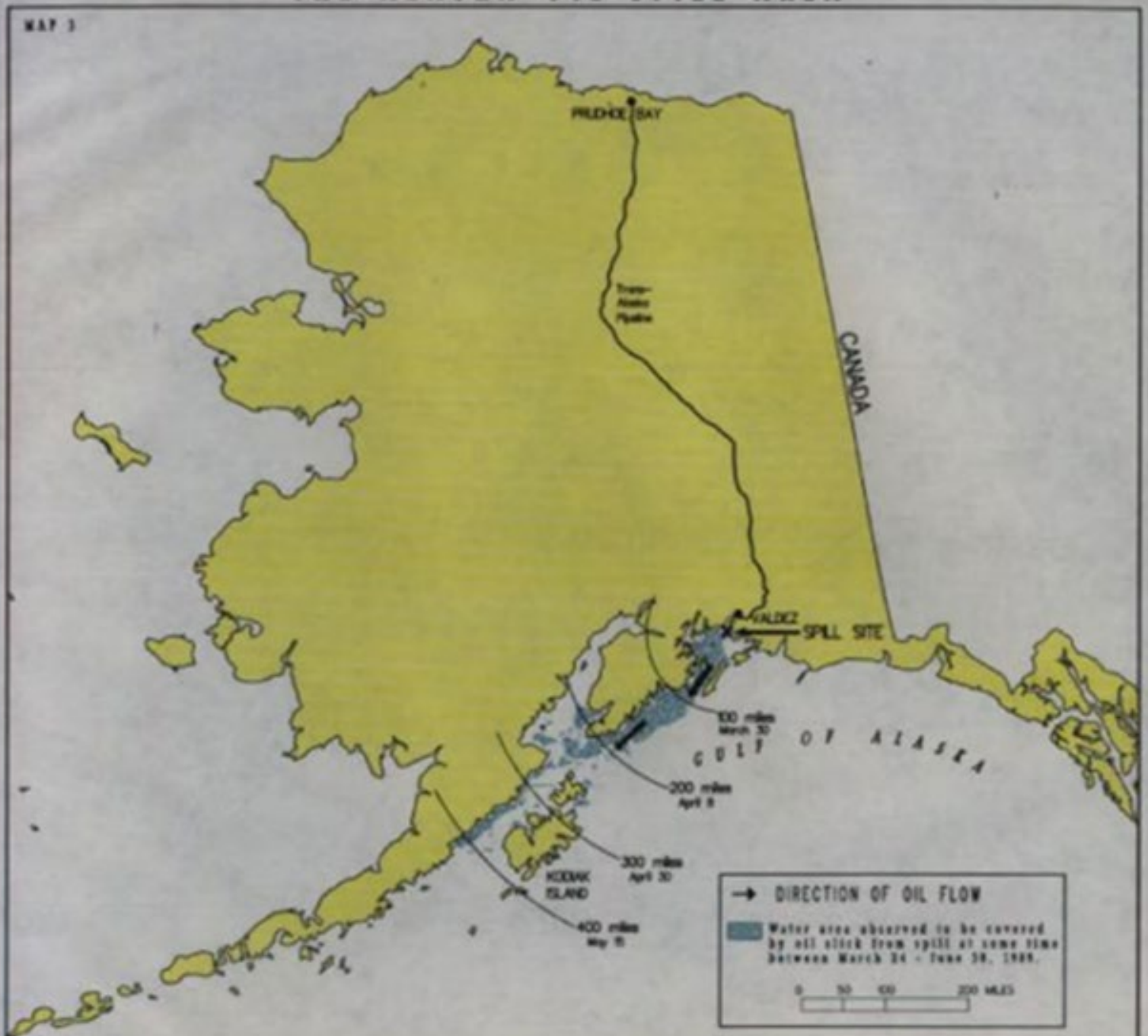
E MURRES

F SEA OTTER

Describing Path and Extent of Shoreline Oiling


MAP 4
THE ALASKA OIL SPILL
PRINCE WILLIAM SOUND
VALDEZ
Trans-Alaska Pipeline
Oil Terminal
Columbia Glacier
SPILL SITE
WHITTIER
CORDOVA
PRINCE WILLIAM SOUND
GULF OF ALASKA
DIRECTION OF OIL FLOW
SHORELINE IMPACT, Summer 1989
Heavy Impact
Moderate - Light Impact

THE ALASKA OIL SPILL AREA

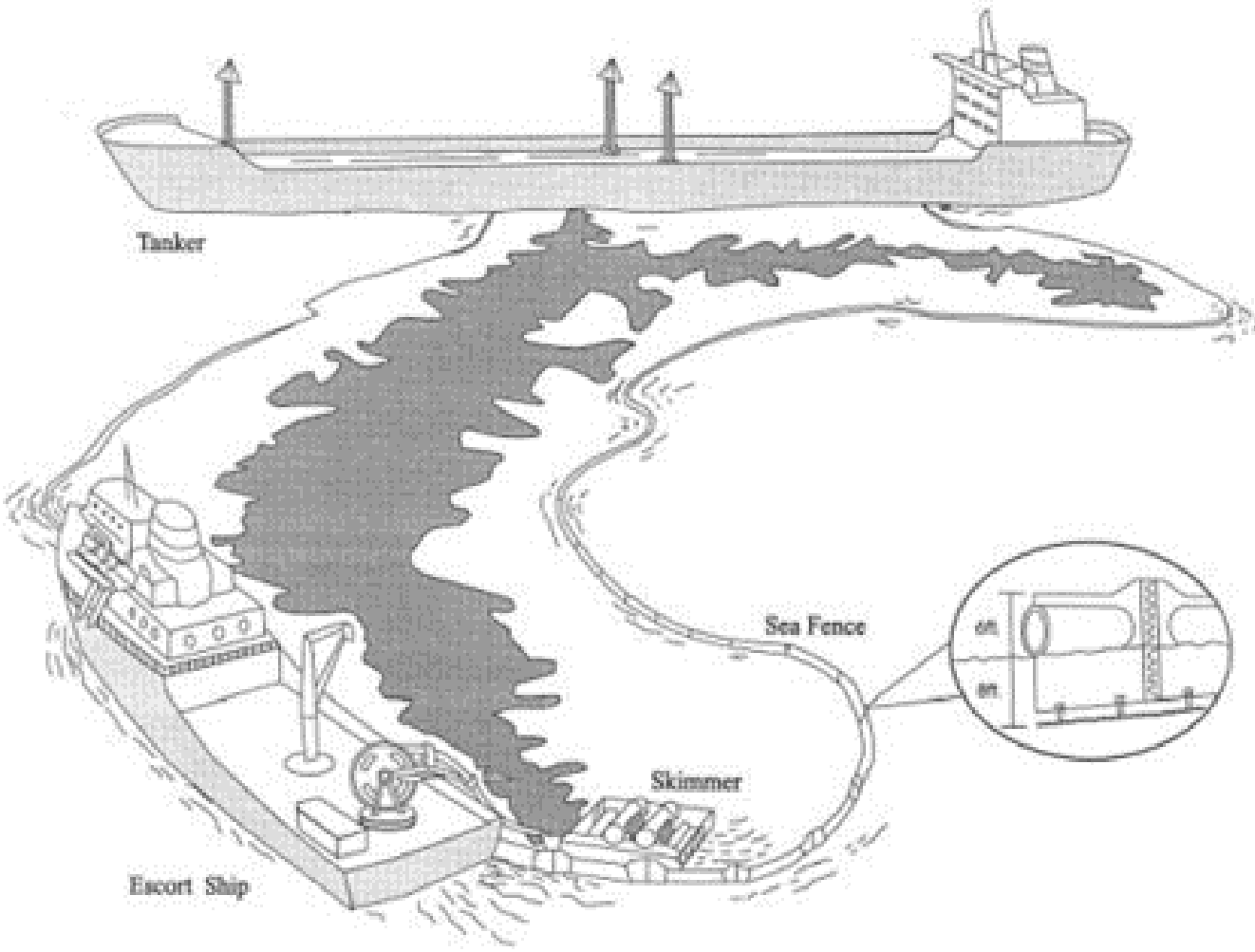


I VERY HEAVILY OILED SHORE BEFORE CLEANUP

J CLEANUP OPERATION ON PRINCE WILLIAM SOUND SHORE, SUMMER 1989

Plan to Prevent Similar Future Spill

- Respondents told risk assessment shows that on average without changes in how tankers operated:
  - 1 very large spill is likely to occur every ten years
  - Matches both actual experience and original risk assessment.
- Plan includes a set of measures ranging from in-port checks (e.g., testing for alcohol intoxication) to being able to monitor path of tanker.
  - Centerpiece of plan is tanker will be accompanied by two ocean going tugs
    - Will be able to keep tanker away from reefs
    - Able to deploy booms to contain oil quickly if spill


Tanker
Sea Fence
Skimmer
Escort Ship

Exxon WTP Question

- "At present government officials estimate that the program will cost your household a total of $X. You would pay this in a special one-time charge in addition to your federal income taxes.

- The money would only be used for the program to prevent another large oil spill in Prince William Sound.

- If the program cost your household a total of $X would you vote for or against the program?
  - $X is randomly assigned to respondent

- Carson et al. Alaska CV study estimated that median willingness to pay for U.S. households to prevent another Exxon Valdez type spill was $30.

- Aggregated to all U.S. households yields an estimate of natural resource damages was **$2.8 billion**.
  - "Total Value" estimate including "Passive Use" considerations

- For comparison, Exxon's experts estimate of natural resources was **$3.8 million** base only on direct use.

Formal Outcomes

- Exxon settles the case out of court for $2.8 billion dollars, by far the largest judgement for natural resources at the time
  - Split between restoration and natural resource damages
  - Natural resource damages paid for off-site or out-of-kind restoration in the form of land for parks/habitat programs
- U.S. Coast Guard uses settlement to justify regulations put prevention & response plan in survey into effect.
  - Spill from sister ship poised to hit nearby reef averted.
- Settlement dramatically changes perceived liability for polluters doing harm to the environment.

NOAA Blue Ribbon Panel

- After Exxon Sponsored Conference, NOAA took unusual step of convening a Blue Ribbon Panel to examine CV.
- Chaired by Ken Arrow and Bob Solow (Nobel Laureates) with Ed Leamer, Roy Radner, Paul Portney and Howard Schuman as the other panel members
- Concluded: "Thus, the Panel concludes that CV studies can produce estimates reliable enough to be the starting point of a judicial process of damage assessment, including lost passive-use values."
- Made recommendations on how to CV that generally followed Exxon Valdez study:
  - Two exceptions
    - Should conduct a test of sensitivity of results to scope of good
    - Should Include a don't know as vote choice options

Broad Scale Attack on CV

- Public facing
  - Media attacks including print ads in major newspapers
  - Hundreds of comments on regulations
- Commissioned attacks
  - Academic pieces with an extreme form of selection bias
  - Coordinated effort create impression CV completely flaky
- Lobbying
  - Congress and executive branch agencies
- Overall effort to discredit CV bore a strong resemblance to earlier attacks on work showing cigarettes caused cancer and burning fossil fuels contributes to global warming
  - Utilized some of the same individuals/organizations

Constructive Academic Work That Followed

- Assessing temporal reliability
- Insuring consequentiality and incentive compatibility
- Scope Sensitivity
  - Understanding theoretical implications of sequencing & nesting
  - Assessment of Exxon's studies
  - Recognition of scope tests contained in earlier studies
  - New empirical tests and identification of problematic areas
    - Low level risk (comprehension) & individual endangered species
- Deeper development of theory for non-marketed goods
  - WTP vs WTA and Income elasticity of WTP
- Implications of formally including a don't know option

Exxon Replication: Temporal Reliability

- Original Exxon study (WESTAT):
  - In 1991: 52% voted in favor of the program
- Replication of Exxon study (NORC):
  - In 1992: 53% voted in favor of the program
- Predictive equations for WTP estimated from the two datasets shown to be statistically equivalent

Preventing Oil Spills on California's Central Coast

(Carson et al., Springer 2004)

- Done with funding from a prior oil spill legal settlement and in response to perceived need to "post" in advance cost of spill.
- Focus is on California's scenic central coast, which our analysis showed was hit with some frequency by medium size oil spills from barges traveling between San Francisco & LA.
- Policy question: how much is the California public willing to pay in terms of higher one-time tax to avoid this?
- Higher cost would cover spill prevention & containment plans & higher cost of moving barge routes further offshore.

Emphasizing Consequentiality

- Proposals are sometimes made to the State for new programs; but the State does not want to start any new programs unless taxpayers are willing to pay the additional cost for them.
- One way for the state to find out about this is to give people like you information about a program so that you can make up your own mind about it
- Your views are useful to State decision makers in deciding what, if anything, to do about a particular situation.
- In interviews of this kind, some people think that the program they are asked about is not needed; Others think that it is. We want to know what you think.

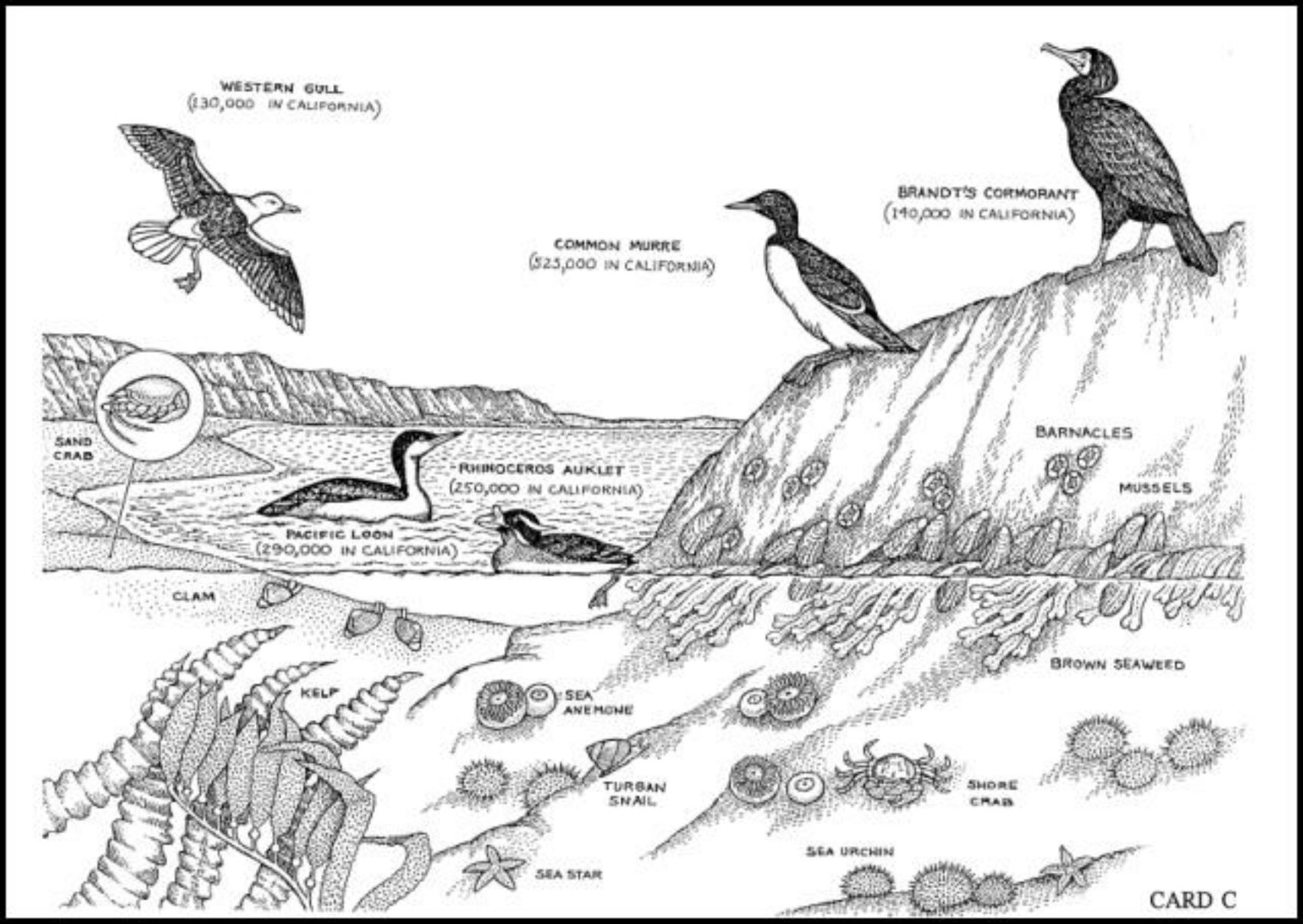

Super-Tanker Routes
Oregon
Crescent City
Eureka
San Francisco
Farallon Islands
Santa Cruz
Central Coast Small Tanker and Barge Route
San Luis Obispo
Ventura
Los Angeles
Channel Islands
San Diego
Mexico

CARD B

Saltwater marsh

Rocky shoreline

Sandy beach


WESTERN GULL
(130,000 IN CALIFORNIA)
COMMON MURRE
(525,000 IN CALIFORNIA)
BRANDT'S CORMORANT
(140,000 IN CALIFORNIA)
SAND CRAB
RHINOCEROS AUKLET
(250,000 IN CALIFORNIA)
PACIFIC LOON
(290,000 IN CALIFORNIA)
BARNACLES
MUSSELS
CLAM
BROWN SEAWEED
KELP
SEA ANEMONE
TURBAN SNAIL
SHORE CRAB
SEA URCHIN
SEA STAR
CARD C

- Median California household willingness to pay (WTP) to prevent oil spills along California's Central coast $61.
  - Non-parametric lower bound on mean willingness to pay $83.
- Translates into over $900 million dollars over 10-year horizon.
- Results used by State to assessing adequacy of spill response plans, and decisions on rerouting barge traffic.
- Posted by State of California as the economic damages from large oil spill in California's central coast region.
  - Outcome: no major ship spills since study done.

Valuing Poaching and Logging Protection Policies for Tropical Forest Ecosystems

(Vincent et al. Proceedings of the National Academy of Sciences, 2014)

- Use a CV survey with a discrete choice experiment (DCE) elicitation format to value changes in policy attributes.
- Study site is in northern Malaysia
- Population interviewed is in greater Kuala Lumpur area
  - Stratified into three subsamples: urban, suburban, rural
- Extensive survey development work

Belum-Temenggor Forest Complex

Belum–Temenggor Forest Map

Source:
1.) Nowista Sdn Bhd
2.) WWF Malaysia

2

Forest

Source: Nowista Sdn Bhd

3

Managing Belum-Temenggor Forest Complex
DCE Attribute Levels

- Respondents given description of Forest Complex & policy options
- Different management options are described in terms of features:
  - number of hectares logged: {*all, half, none*}
  - number of hectares protected from poaching: {*all, half, none*}
  - number of floods in Perak (tied directly to logging): {*5, 3, 1*}
  - number of jobs created: {*7500, 5000, 2500*}
  - cost to the household in terms of a higher water bill that all households would pay {*no cost, 2, 6, 10*}
- Respondents are given four choice sets
  - Each has 3 options: status quo management & 2 alternatives

Baseline (Status Quo)

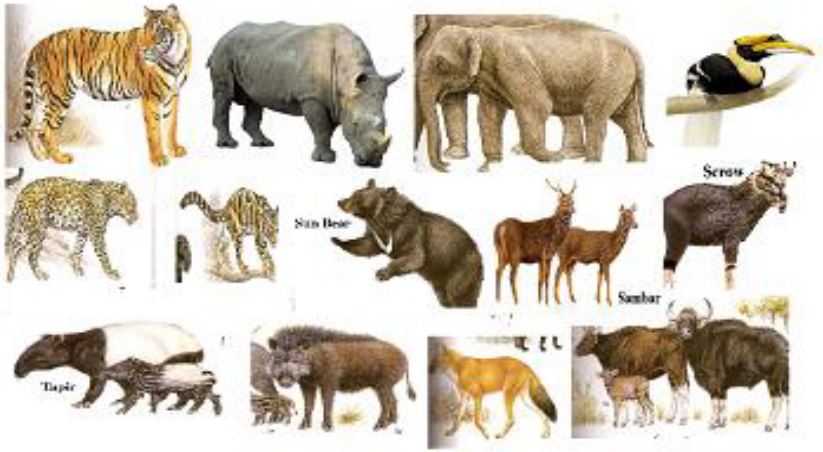
If the Government Protects Nothing

Logging: In all the forest
(0 ha protected)

All these species disappear

Poaching: In all the forest
(0 hectares protected)

All these species disappear

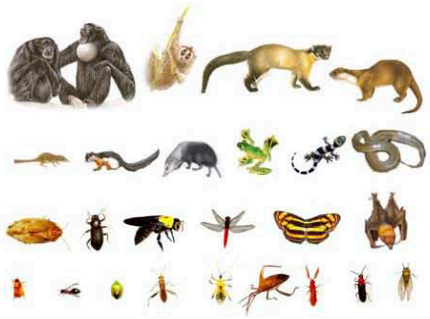


Floods in Perak: 4-6 times a year

Jobs created in Perak: 7,500

No new costs to you or the government

Representative Module 1 Choice Set

	Policy C	Policy D	No protection
Logging	300,000 ha	150,000 ha	300,000 ha
	All these species go extinct	Half these species go extinct	All these species go extinct
Poaching	0 ha	150,000 ha	300,000 ha
	None of these species go extinct	Half these species go extinct	All these species go extinct
Floods in Perak	5 per year	3 per year	5 per year
Jobs created in Perak	2,500	5,000	7,500
Cost to you	RM10 per month	RM10 per month	No cost

Comparison Across Locations: Conditional Logit

	General	Kuala Lumpur	Selangor suburban	Selangor rural
Price	-0.140***	-0.169***	-0.115***	-0.147***
Logging	0.856***	0.846***	0.830***	0.899***
Poaching	0.576***	0.668***	0.646***	0.460***
Jobs	0.012	0.022	0.012	0.008
N *-LL*	15126 4555	3660 1088	5562 1646	5904 1802

*, **, *** ~ 10, 5, 1 % statistical significant

Ratio				
Logging/ Poaching	1.49	1.27	1.29	1.95
MWTP (RM per month)				
Logging	6.10	5.01	7.22	6.10
Poaching	4.10	3.95	5.62	3.12

Further Discussion of CV Issues

DCE Versus Binary Discrete Choice CV Question

- A single binary discrete choice question is simplest DCE.
  - Status quo versus a single alternative
  - Single choice set
- Best incentive properties among class of DCE elicitation formats
- Amenable to simple non-parametric modeling in contrast to complex logit-type models needed for more general DCEs.
- Any DCE (alternatives, choice sets, attributes) implementable in a set of single binary CV question using independent samples.
  - Internal (with-subject) vs. external (between) test(s) of scope
- Main reason for DCE usage is substantial reduction in cost for amount of information obtained about attributes.
  - This cost factor is very important, particularly when a range of policy options are being considered.

Consequentiality & Incentive Compatibility

(Carson and Groves, ERE, 2007)

- For the response to a CV survey to be interpretable as revealed economic behavior it needs to be perceived as consequential.
  - Potentially influences a policy that respondent cares about.
- For the response to a CV survey question to be incentive compatible in the sense that it is in the self-interest of the respondent to truthfully reveal their preferences, question:
  - Also needs to be a single binary discrete choice question posing a take-it-or leave offer potentially influencing a single issue.

Consequentiality & Incentive Compatibility

(Carson & Groves (2007): Properties of Surveys & Elicitation Formats)

- Recognize popular extreme approach of telling respondents that their answers would not influence anything misguided.
  - Carson and Groves show that to reveal economic behavior survey need to be consequential: potentially influences decision respondent cares about. Pure hypothetical question: **inconsequential**.
- Show truthful preference revelation optimal in binary discrete choice question (with auxiliary take-it-or leave-it conditions) for pure public good with **coercive payment** mechanism.
  - Deviations from other elicitation formats generally predictable and can tradeoff bias in a known direction for reduced variance.
- Under reasonable assumptions, marginal tradeoffs estimates between attributes are unbiased even if total WTP is not.

Role of Development Work

(For a 30 to 60-minute survey on one issue)

- Tools
  - Focus groups, in-depth interviews, group (hotel) administrations, pretests, and pilot studies,
- Understanding of & language used to describe key concepts
  - Often quite different from that used by experts
- Visual aids
- Divergent beliefs in CV scenarios
  - Often revolve around lack of trust in government to either deliver or only collect the cost amount stated in survey
- Flow of information toward a singled purpose
- Final CV survey instrument as a source of face validity.
  Often useful even if data never collected for main study.

CV Critiques

- Use of CV remains controversial in large part because it can substantially increase economic value attributed to improvement/damage to environmental goods/services
- Critics raise a range of potential problems:
  - Hypothetical bias
  - Preferences for unfamiliar goods may be ill-defined
  - Possibility of "yea-saying" to please interviewer
  - Values are due to "warm glow"
  - Some study findings do not conform to theoretical predictions
  - WTP estimate sensitivity to context information
    - e.g., payment vehicle, who provides the good
  - Claims that CV overestimate WTP? Comparisons to:
    - RP-based estimates, private goods, voluntary contributions

Production Function Approach

- Treats an ecosystem service explicitly as an unpriced production input.
- Three basic functional representations:
  - Production function: purely technical relationship
    - Epidemiology, fisheries population dynamics are special cases
  - Cost function
    - Specifies the function describing cost of market inputs used
  - Profit function
    - Multiplies output X market value – cost function
    - Output specified in terms of production function
    - Marketed inputs chosen to to maximize profits
    - If good doesn't have market price: unit value (value of time)

What Does the Profit Function Look Like?

- Profit function (Π)
  - Revenue – cost (straightforward if competitive)
  - $p \cdot q - w \cdot x$
  - $p \cdot \alpha x^{\beta} E^{\gamma} - w \cdot x$ (technical production substituted)
- Maximize by setting derivative of Π with respect to x equal o $[p \cdot \alpha x^{(\beta - 1)} E^{\gamma} - w] = o$
  - Yields factor payment to x of $w = p \cdot \alpha x^{(\beta - 1)} E^{\gamma}$
  - Both Π and w depend upon E and its productivity parameter γ
- E assumed not under firm's control but can ask the question what happens to Π if $E_o \rightarrow E_1$
- Will usually get both a new x, w and Π
- **Difference in profits (with optimal marketed inputs) is the economic value of the change from $E_o \rightarrow E_1$**

Coastal Wetlands Reduce Property Damage During Tropical Cyclones

(Sun and Carson, Proceedings of the National Academy of Sciences, 2020)

- U.S. is frequently hit by tropical cyclones
  - Between 1996-2016, 88 tropical cyclones hit 236 coastal counties
- Damage from tropical storms is caused by storm surge, wind, and flooding. It can be reduced by:
  - Hardening infrastructure, building codes, disaster response effort
  - Wetlands
- Paper provide spatially delineated estimates of the marginal value of wetland preservation in preventing property damage

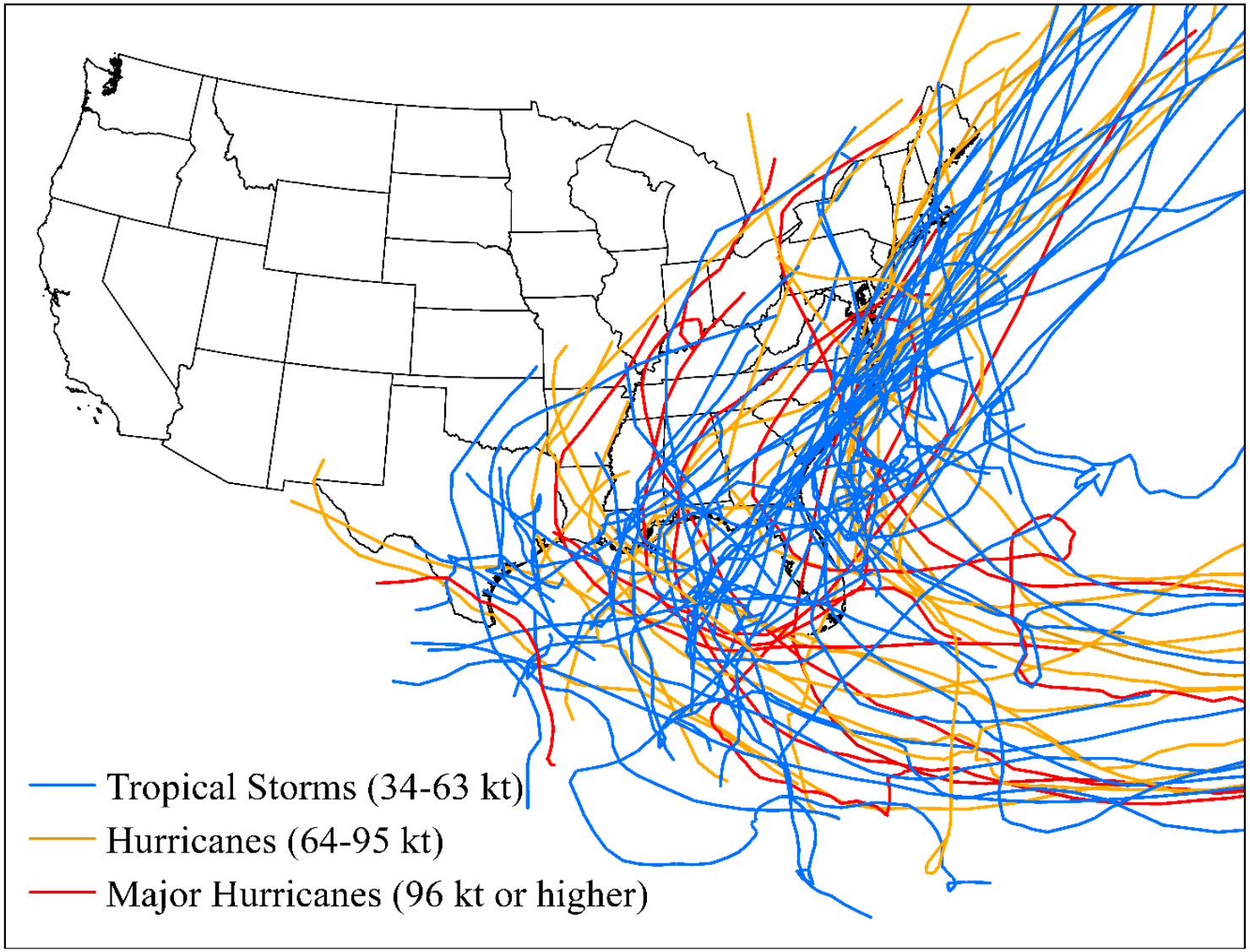
Overview of Paper

- U.S. is frequently hit by tropical cyclones
  - Between 1996-2016, 88 tropical cyclones hit 236 coastal counties
- Damage from tropical storms is caused by storm surge, wind, and flooding. It can be reduced by:
  - Hardening infrastructure
  - Building codes
  - Disaster response effort
  - Wetlands
- We provide spatially delineated estimates of the marginal value of wetland preservation/restoration in preventing property damage

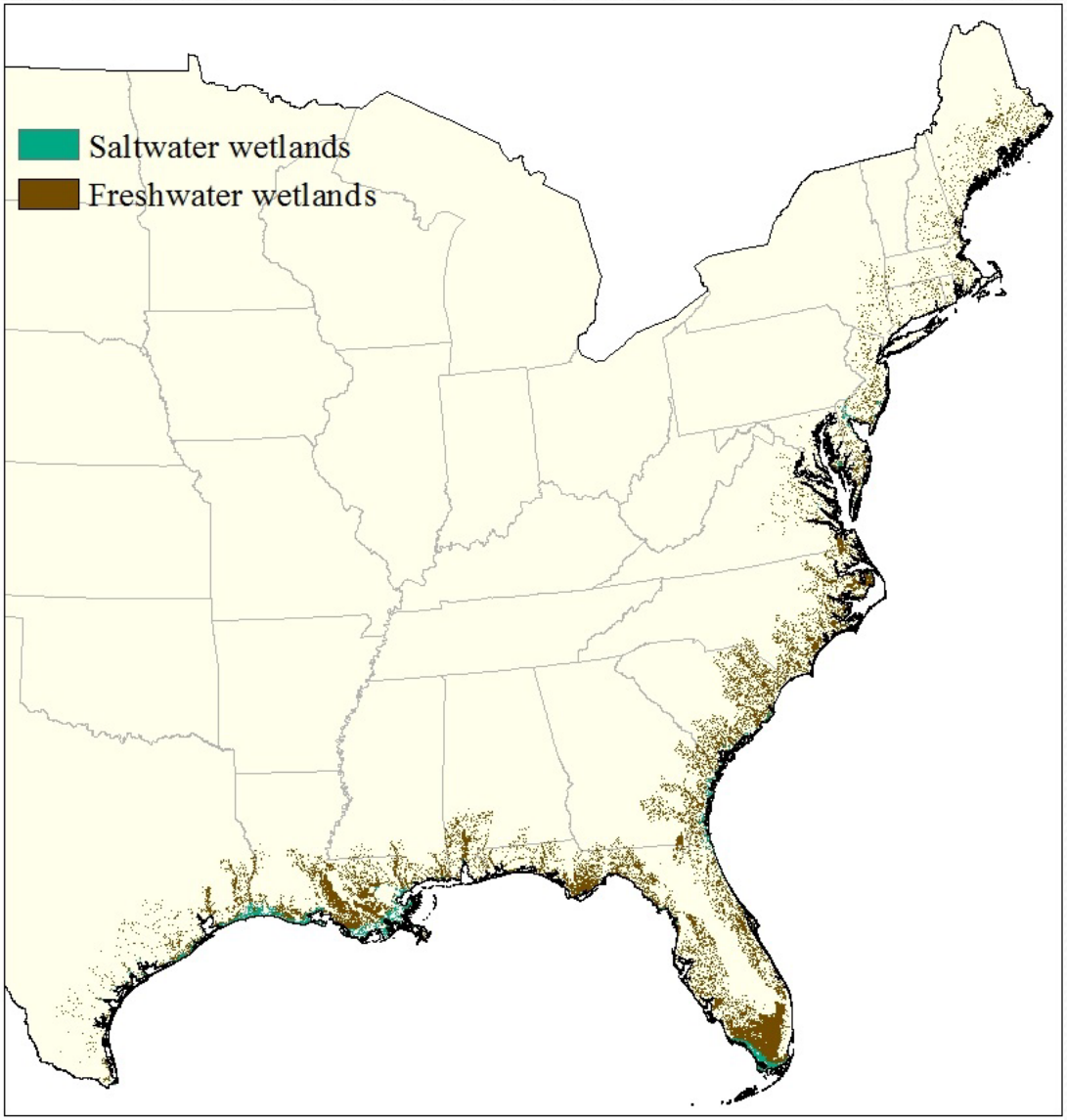
Construction of Geospatial Variables

- Areas hit by each tropical cyclone
- Wind speed that hit area
- Angle at which area was hit by storm
  - Right: push water onshore
  - Left: blow water away from the coast
- Area at risk of storm surge as a function of elevation and other physical variables
- Wetlands
  - Quantity over time
  - Location
  - Type (freshwater v. saltwater) and (forested v. non-forested)
- Property values at risk at Census block group level

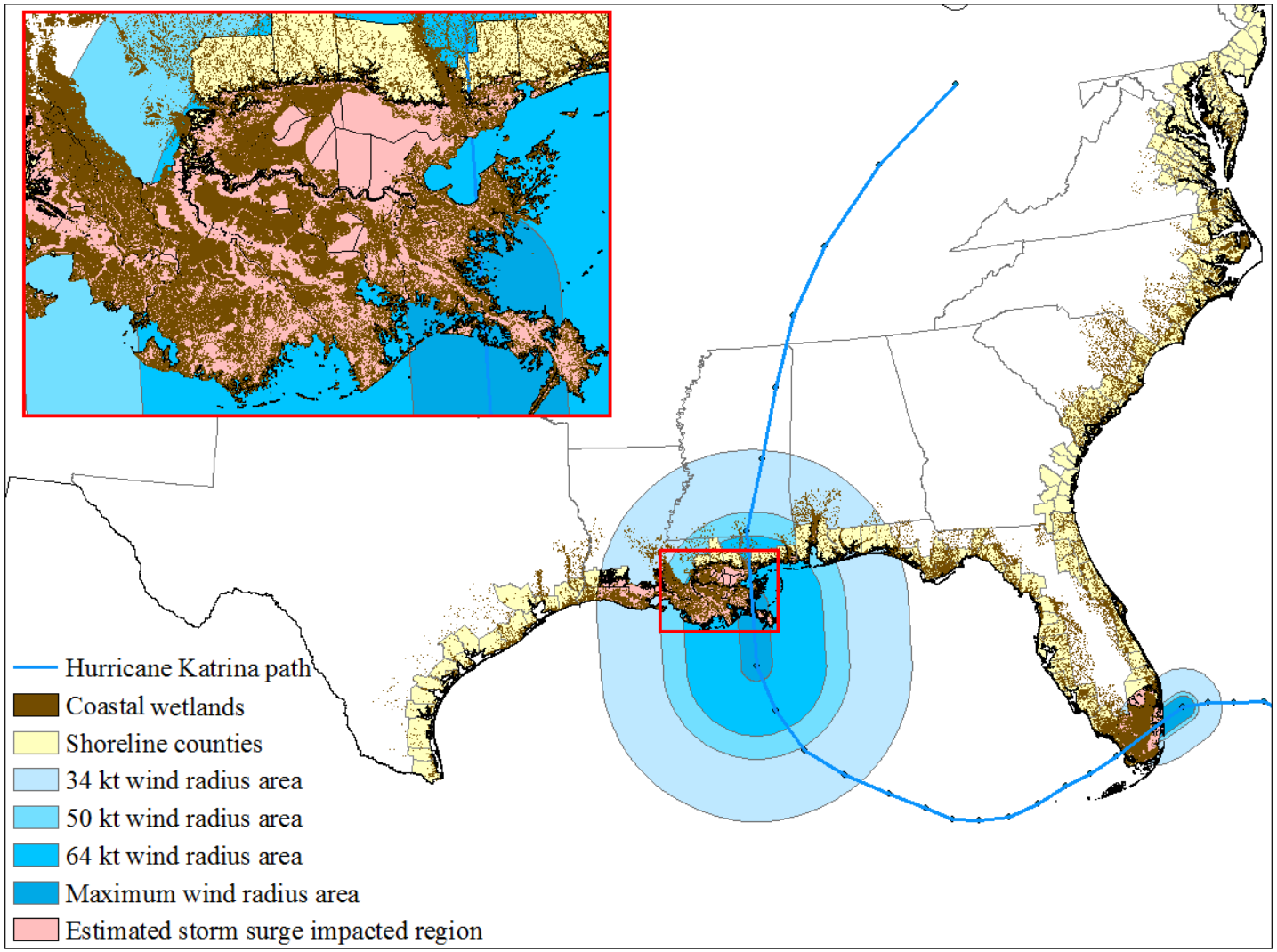
Tropical Cyclones Hitting the U.S. 1996-2016



Coastal Wetlands Coverage in 2010 – 154,000km^2



Example: Hurricane Katrina



Model: First and Second Stages

$$P(damage_{csht} > 0|X) = \Phi(\gamma_0 + \gamma_1 wetland_{csht} + \gamma_2 wind_{csht} + \gamma_3 stormarea_{csht} + \gamma_4 riskproperty_{csht} + \gamma_5 right_{csht} + \eta_{csht}), \quad (1)$$

$$\ln(damage)_{csht} = \beta_0 + \beta_1 \ln(wetland)_{csht} + \beta_2 \ln(wind)_{csht} + \beta_3 \ln(stormarea)_{csht} + \beta_4 \ln(riskproperty)_{csht} + \beta_5 right_{csht} + \gamma_s + \lambda_t + \varepsilon_{csht}, \quad (2)$$

- c = county, s = state, h = storm, t = year
- $damage_{csht}$ = property damage.
- $wetland_{csht}$ = wetland area within the storm surge impact region.
- $wind_{csht}$ = maximum sustained wind speed.
- $stormarea_{csht}$ = potential storm surge impact zone.
- $riskproperty_{csht}$ = total property value under the risk of flooding.
- $right_{csht}$ = 1 if located to the right of the storm path, and 0 otherwise.
- $state_s$ and λ_t = state and year fixed effects.

First Stage: Probability Damage > 0

- 65% of the time a county was hit by tropical cyclone winds, no property damage reported.
- Probit model shows
  - Probability of positive reported damage increasing in:
    - wind speed, storm impact area, being hit on storm's right side
  - Decreasing in wetland coverage
  - Property value at risk not a significant predictor
- Large random component
  - Tides, very specific storm track, gusts, rainfall
  - 207 of 236 coastal counties hit had damage at least once

Second Stage: Conditional Damage Model

- Conditional damage model shows
  - Wetlands significantly reduce property damage.
  - The wind effect is particularly large.
  - Being hit at right angle increases property damage by 140%.
  - Damages are increasing but a scale less than 1 in terms of storm area and property value at risk.

Results for Eq.(2) – wetlands↓1%, damage↑0.6%.

	(1) Damage
log(wetland)	-0.5756***
	(0.1840)
log(wind)	7.1885***
	(0.5653)
Right	0.8821***
	(0.3129)
log(storm area)	0.4793**
	(0.2249)
log(property at risk)	0.3205***
	(0.0622)
State FE	Yes
Year FE	Yes
N	946
Adj. R^2	0.52

Standard errors are clustered two-ways at the county level and the hurricane level. *p<0.10, **p<0.05, ***p <0.01.

Do Different Types of Wetlands Provide Different Protection?

- Differentiate between freshwater and saltwater wetlands
  - No significant difference in the protection provided
- Differentiate between forested and non-forested wetlands
  - No significant difference in the protection provided
- Consistent with the contradictory claims in the science literature on the protective value of different types of wetlands

Value of Storm Protection Services

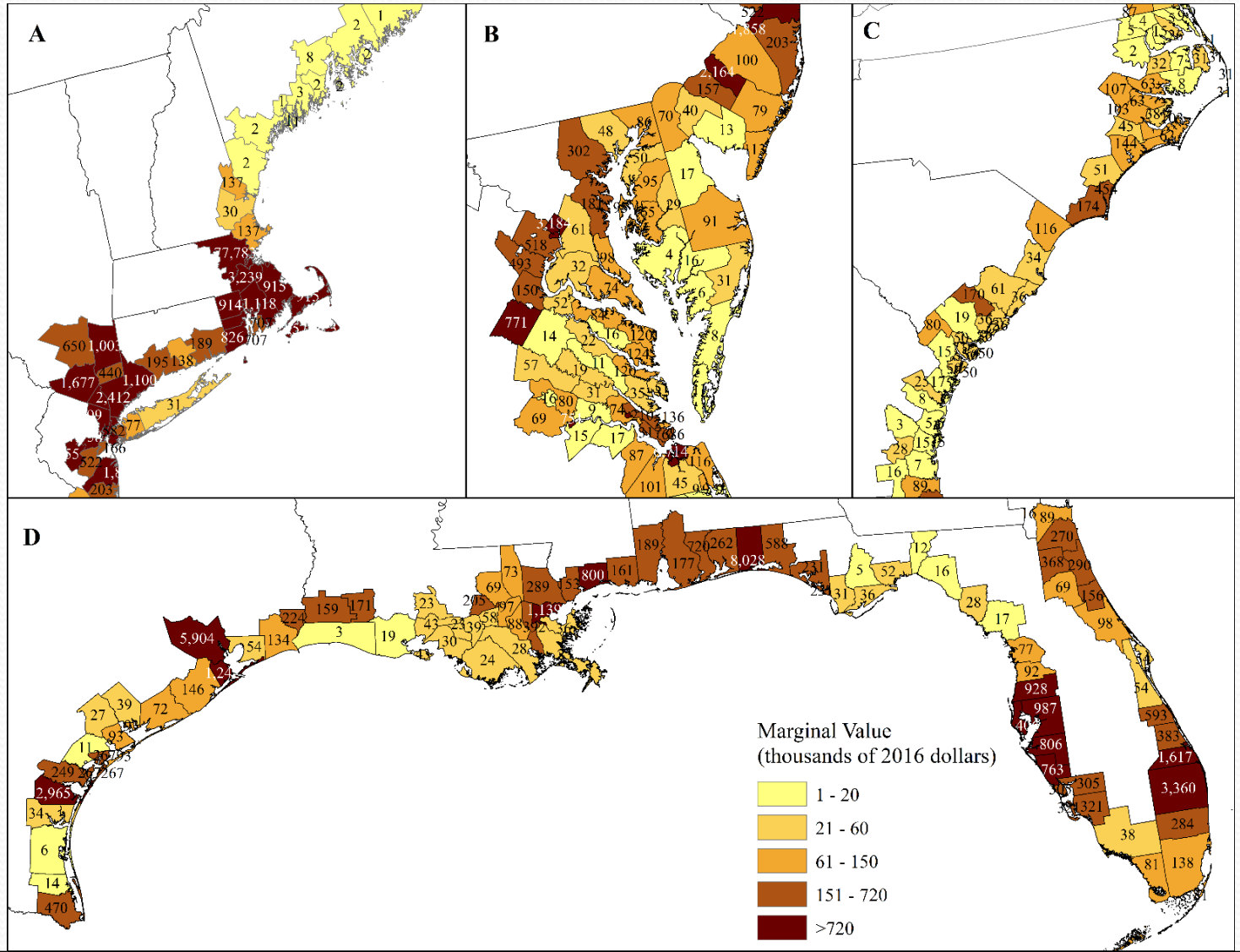
- In terms of providing/preserving an additional km^2 (~250 acres) of coastal wetlands per year

- Estimation:

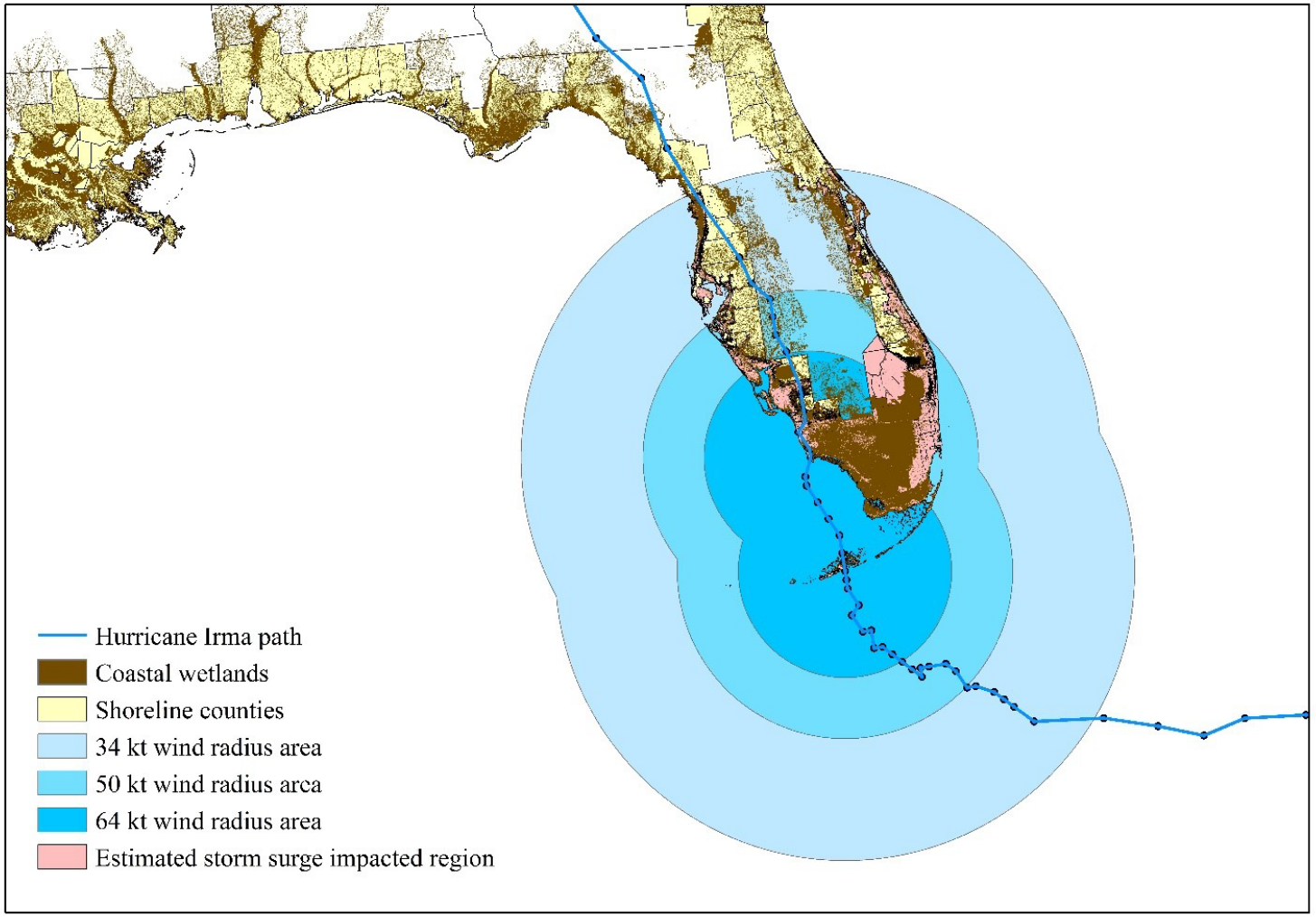
$$\frac{\partial E(D)}{\partial W} = \frac{\partial \int P(D > 0|v, X_{-v}) E(D|v, X_{-v}, D > 0) f(v) dv}{\partial W}$$

- Integrate over wind distribution *f(v)*
  - U.S. Landfalling Hurricane Probability Project
  - Selected quantiles fit using min. distance for Gamma dist.
  - Upper integration bound: 152kt (Hurricane Camille, 1969)

Annual Marginal Value of Coastal Wetlands For Property Damage Prevention ($1,000/km^2)



Model Can Be Used With New Tropical Cyclone Hurricane Irma (2017)



Projection to Hurricane Irma

- Since 1996, Florida has lost 2.8% of the wetlands in the 19 coastal counties impacted by Hurricane Irma at tropical storm or greater wind speeds.

- Model estimates that this loss of wetlands increased property damage by ~ $400 million dollars.
  - Out of ~$40 billion dollars in property damage

Conceptual Framework For Travel Cost Method (TCM)

- The “price” of using a recreation site is not only the entry fee (possibly zero), but also the monetary and time costs of traveling to it.
- Visitors who live at different distances from the site thus face different implicit prices.
- We can estimate a demand curve for the site by relating the number of visits to the total travel cost

History of the Travel Cost Method

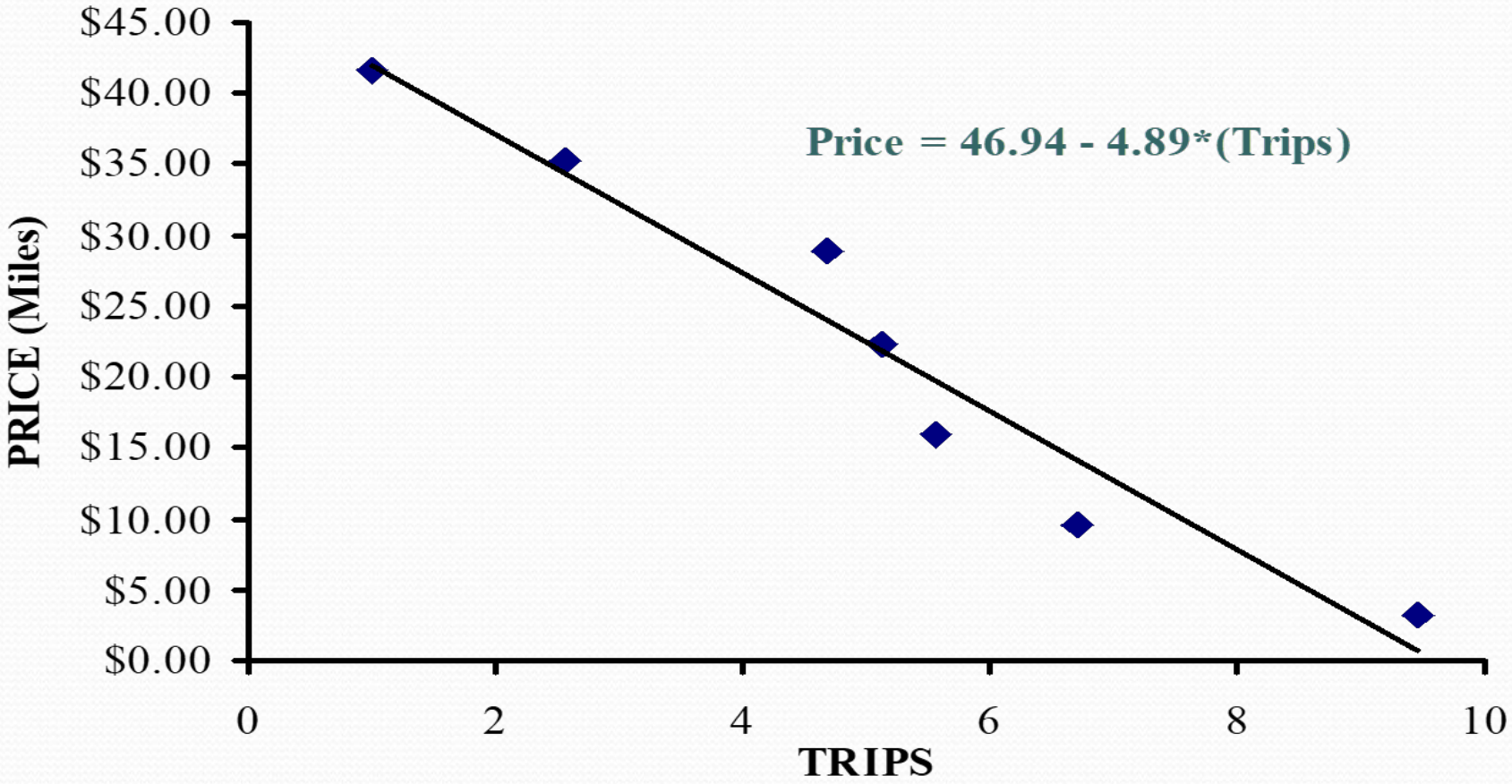
- Concept is due to Harold Hotelling, in response to request from National Park Service in late 1930s
- Operationalized by Marion Clawson in 1950s and refined by Clawson & Jack Knetsch in the 1960s
- Gary Becker later proposes household production approach (combining both market and nonmarket goods) to provide household with utility.
  - Travel cost analysis & Averting behavior are special cases

Hotelling's Original Insight

- Take a recreation site
- Draw circles around with site as origin using different distances as circle's radius
  - 1 km, 2 km, 5 km, 10 km, 15 km, 20 km, ect.
- Observe where visitors to site came from
  - Through sign in sheet at park or vehicle license plates
- Calculate visitation rate:
  - fraction of population visiting park from each ring (circle of a particular radius minus smaller rings/original circle)
- Visitation rate (typically) falls as distance from site increases
- Cost of visiting site increases as distance increases

How Does TCM Work?

Average Number of Trips to Ohio's Headlands State Park Beach



- Economic value of a trip to site is $46.94.

Typical Steps in Estimating Individual Site Model

1. Define the site to be valued
2. Define the recreation uses and time frame
3. Decide on the treatment of multiple purpose trips
4. Determine per km travel cost & for time cost (e.g., 1/2 wage rate)
5. Determine population of interest/develop a sampling strategy
6. Specify the underlying statistical demand model
7. Design and implement the survey to determine trips taken to site, what substitute sites are and consumer characteristics
8. Collect information from respondents on trip origin and calculate travel distance and travel time for each trip
9. Estimate the statistical demand model
10. Calculate consumer surplus value

The Multi-Site Recreational Choice Model

- Multi-site model is not based on a "quantity demanded approach", but rather describes demand for recreation as a **problem of choice among alternatives**.
- Statistical model used is the random utility model (RUM) used to study many location and transportation issues.
- Choices are explained by site attributes (characteristics).
  - Same framework as DCE elicitation format in CV studies.
- Respondents choose site that give them the highest level of utility.
- Model allows analysis of behaviour of agents when they face a site choice problem even when number of alternative sites is large
  - Use random sampling of sites not chosen plus chosen site

Southcentral Alaska Recreational Fishing Study (Carson, Hanemann and Wegge, MRE, 2009)

- Multiple waves of trip diary surveys to Alaskan household with fishing license (1063 respondents)
- Model recreational fishing behavior & expenditures in the main part of Alaska where people live.
  - 13 species of types of fish
  - 29 locations
  - 22 weeks
  - ~30 million implicit choices

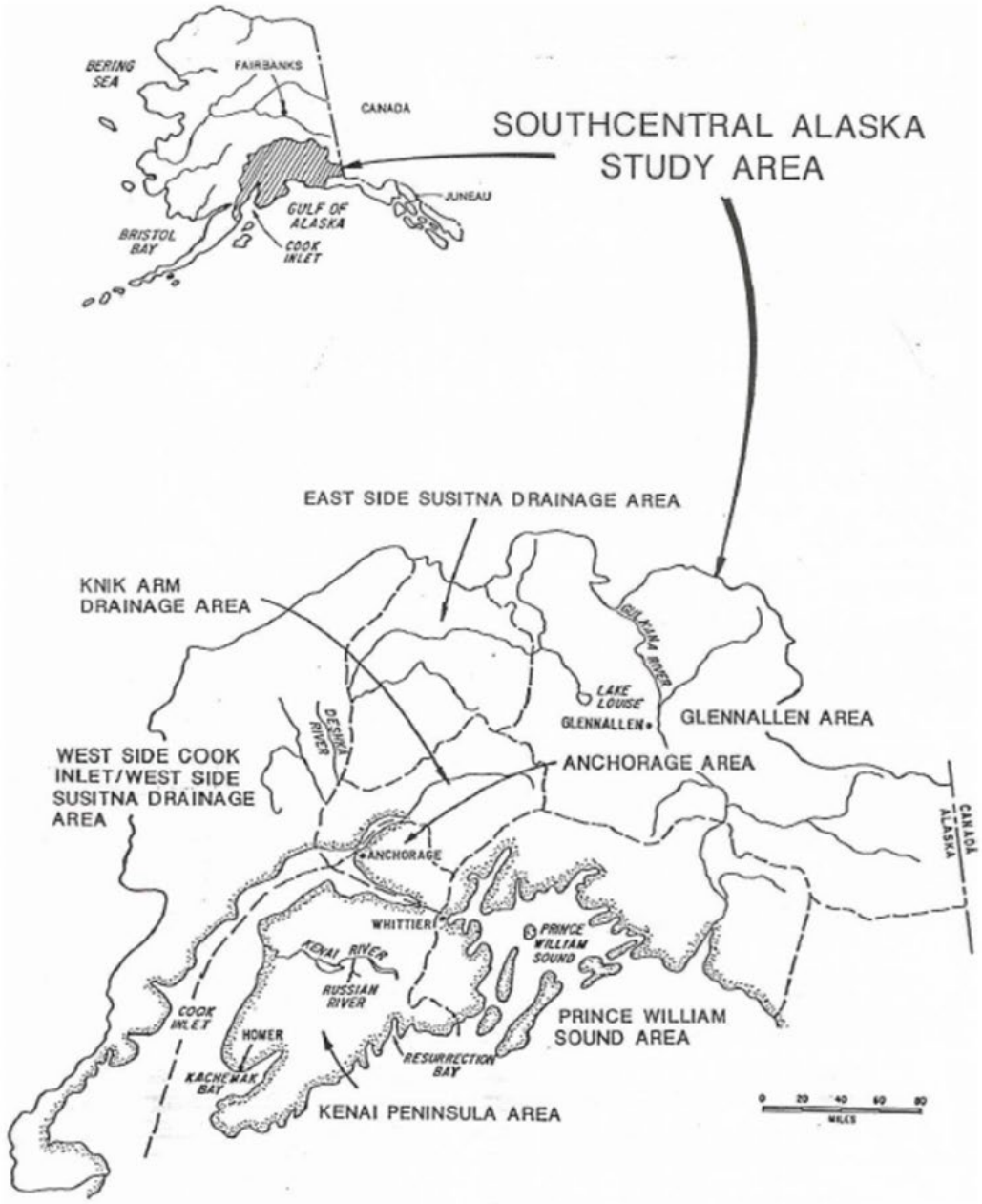


Figure 1. Southcentral Alaska Study Area

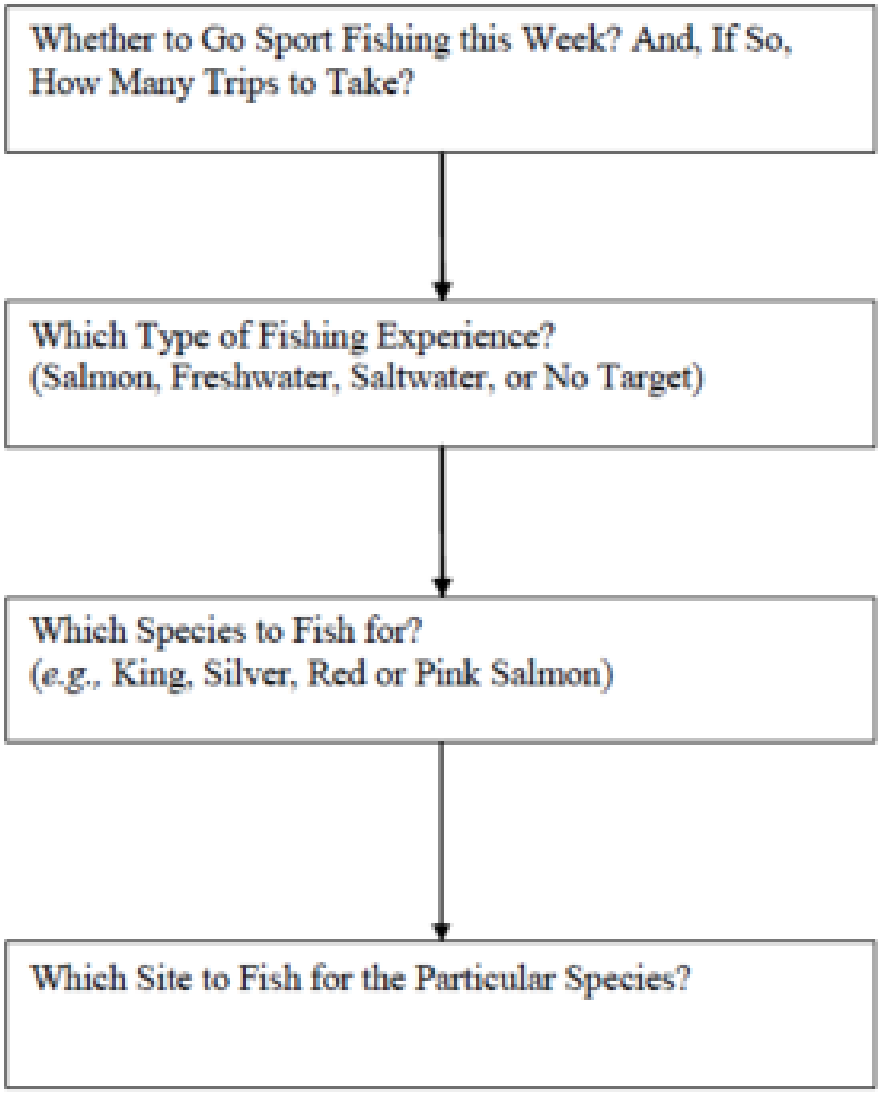


Figure 2. Conceptual Decision Tree for Analyzing Resident Angler Demand for Sport Fishing

Table 1

Species Groups (and Abbreviations) Used for the Analysis of Sport Fishing Demand

Group	Species Group
1	King salmon (KS), including small king salmon (KI)
2	Red salmon (RS)
3	Silver salmon (SS)
4	Pink salmon (PS)
5	Rainbow trout (RT) and land-locked salmon (LL)
6	Dolly Varden (DV) and Arctic char (AC)
7	Lake trout (LT)
8	Arctic grayling (GR)
9	Other freshwater species—chum salmon (CS), steelhead trout (SH), cutthroat trout (CT), brook trout (BT), northern pike (NP), shellfish (SF), whitefish–freshwater (WFF), burbot (BB)
10	Halibut (HA)
11	Razor clams (RC)
12	Other saltwater species—rockfish/seabass (RF/SB), smelt/hooligan/capelin (SM), other finfish (OF), whitefish–saltwater (WFS), other shellfish (OS)
13	No target (NT)

- Site choices are characterized by attributes such as measures of fishing quality, crowding, temperature.
  - Allows for examining economic effects of changing quality.

- Sites can be available or unavailable in specific weeks for particular species.
  - One way of modelling possible averting behavior.
  - Allows for estimating economic loss from closures.

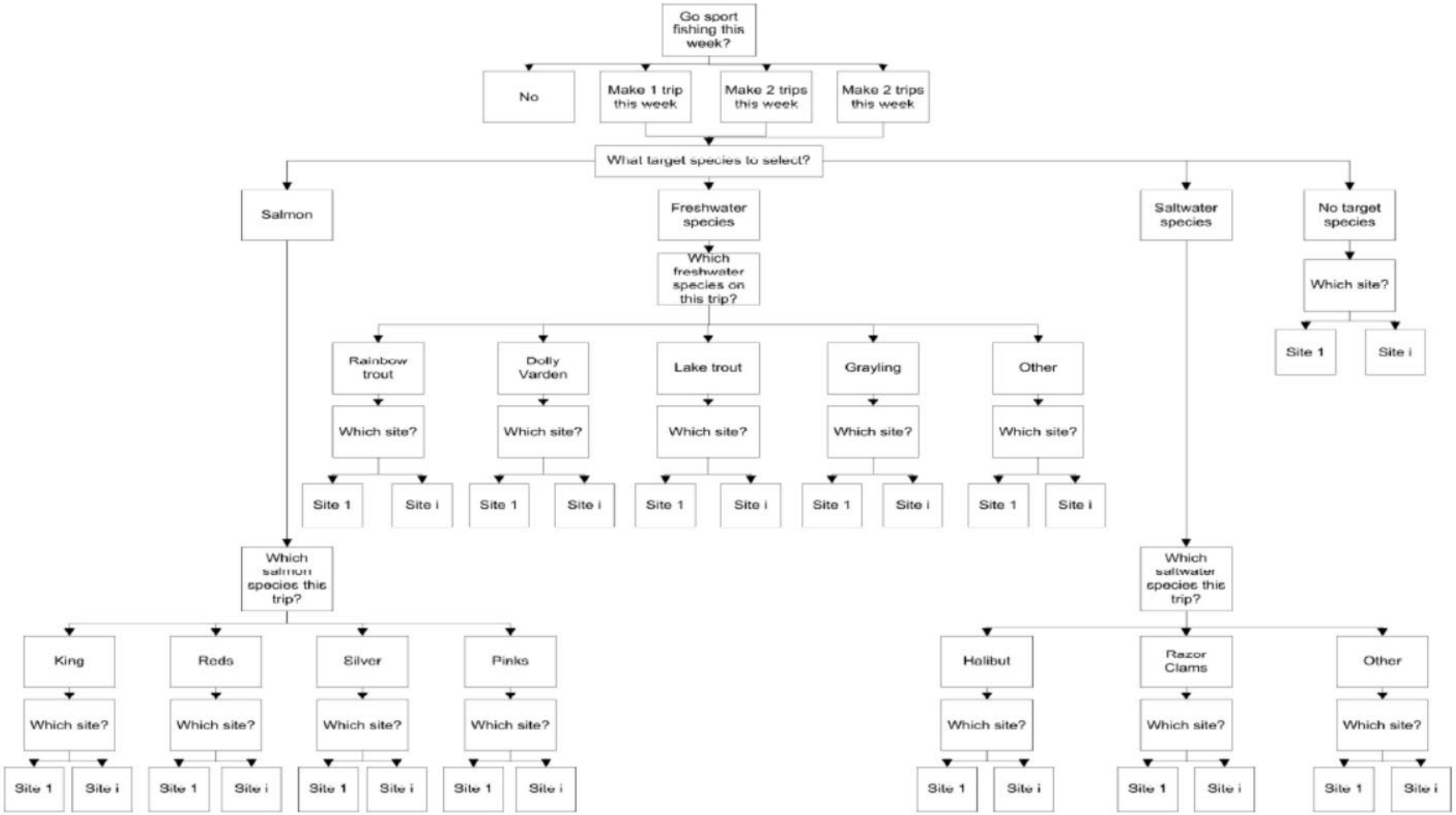


Figure 3. Detailed Decision Tree for Analyzing Resident Angler Demand for Sport Fishing

Probability of Taking a King Salmon Trip
During Week 13 to Different Sites, When King
Salmon is the Target Species

Site	Probability with Kenai River Kings Available	Probability without Kenai River Kings Available
1	.0118	.0351
2	.0170	.0455
3	.0039	.0097
16	.4565	--
17	.2037	--
19	.1106	.4492
22	.0450	.1338
23	.0090	.0285
24	.0195	.0566
25	.0091	.0278
26	.0084	.0249
27	.0133	.0366
28	.0747	.1231
29	.0176	.0292

Choice Probabilities for Salmon Species, Type of Fishing, and Number of Fishing Trips With and Without Kenai River King Salmon Available

Choice Type	Probability with Kenai River Kings Available	Probability without Kenai River Kings Available
Salmon Species		
kings	.2434	.1066
reds	.3397	.4011
silvers	.3277	.3861
pinks	.0892	.1054
Type of Fishing		
saltwater	.1042	.1119
salmon	.5349	.5006
fresh water	.2278	.2446
no target	.1332	.1430
Number of Fishing Trips		
0	.7083	.7123
1	.2614	.2581
2	.0269	.0263
3 or more	.0034	.0033

IMPACT OF CLOSING KENAI RIVER TO KING SALMON FISHING IN WEEK 13

- Reduction in total number of fishing trips: 692
- Reallocation of fishing trips: 45,702
- Reduction in total consumer surplus: $482,000
- Reduction in expenditures on fishing: $100,700
  - From regional input-output model coupled to fishing trip generation RUM model.

Averting Behavior

- Underlying theoretical framework identical to that of multi-site RUM travel cost models.
  - Impacts of spill like advisories not to eat fish now become product/site attributes or impact site availability.
- Often now implemented in this form but two other variants are also common:
  - Natural experiments: look at how a spill shifts demand for products/services used to help avert (mitigate) adverse impacts due to spill.
  - Hedonic pricing: look how spill influences prices for a good or service that includes spill impacts as attributes.
- How to model consumer information always key issue

Examples of Averting Behavior

- Mercury contamination in three locations in the state of Oregon reduces hunting for game birds resulting in a consumer surplus loss of $1.3 million (Shulstad et al., Land Economics, 1978)
- Consumption advisories for PCB contamination in recreational fishery reduces fish and alters trip pattern resulting in $47 lost consumer surplus per Tennessee angler (Jakus et al., AJAE, 1998).
- Notification of low-risk contaminants in drinking water increases bottled water sales 22% (Graff Zivin et al., AER, 2011).
- Radiation warnings related to Fukushima nuclear disaster reduces price of oysters from region relative to other oysters (Wakamatsu, Marine Policy, 2021).

Hedonic Pricing

- Key concept: a good bought and sold in marketplace can be best seen as a bundle of attributes.
  - Similar to a DCE which is the stated-preference variant.
- Three primary type of environmental applications
  - Hedonic wage equation: higher risk [e.g., mortality] jobs (holding other job characteristics constant) pay more
    - Risk premium used to estimate value of a statistical life
  - Hedonic property equation: houses are bundles of physical characteristics [e.g., bedrooms] and locational amenities [e.g., air pollution, crime].
    - Economic value of an air quality improvement is difference in predicted price of otherwise statistical equivalent houses in areas with different air quality levels.

Hedonic Pricing (continued)

- Hedonic product regression: product is a bundle of attributes [e.g., different computer components]. Regression of price on attributes reveals market value of attributes.
  - Regress prices of a particular species of fish taken from different locations on an objective measure of contamination. Estimates reveal economic (loss) in value from that contamination.
  - Reputation impacts can be treated similar using a subjective measure of contamination.

Some Other Not Strictly Economic Approaches: Replacement Costs

- Insurers are comfortable reimbursing losses as:
  - Cost of replacement – Depreciation – Residual Value
  - Depreciation not an issue if replacement good is of similar age/condition and damaged good has no value
    - Major car wreck: purchase replacement car of same year
- Good approximation of economic loss in many cases
  - Replacing oiled fishing nets by paying out price of new ones
- However, an agent would given a fixed insurance payment, purchase something other than damaged good
- Actual replacement cost for many environmental goods and services is often extremely large or infinite

Prices in Similar Markets

- Once a market (e.g., fresh fish) is closed completely or substantively due to an accident, often prices in similar but unimpacted markets are used instead.
  - Conceptually a form of benefit transfer.
- Works if there is:
  - A world price for good and local production relatively small, or
  - No spill overs between closed market and market now used for price information and two markets similar before spill.
- Formal statistical methods (e.g., synthetic cohorts) exists for assessing validity of this assumption.

Habitat Equivalency Analysis

- Uses an ecosystem services approach (not taking account of human uses) to ask whether a particular piece of land is a substitute for the land harmed.
- Relatively uncontroversial if land is in the same general location (on-site) and provides similar services (in-kind).
  - Thought by many ecological researchers and almost all economists not to work when off-site and out of kind

Location/Type	In-Kind	Out-of-Kind
On Site		
Off Site		

Some Concluding Thoughts

- Literature on determining economic values for changes in environmental goods and services is extreme large.
  - Now possible to search literature and use formal tools of benefit transfer to get reasonable starting estimates of many impacts.
- Broad tool kit of nonmarket valuation techniques is available for conducting original studies when high precision needed.
  - Necessary expense and time for conducting largely dependent on need for original data collection and precision
- In countries where government has seriously embraced the "polluter pays" principle, routine & accidental discharges fall.
  - Often requires substantive changes in laws, regulation and enforcement budgets to achieve.